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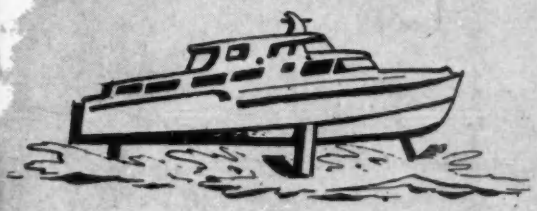
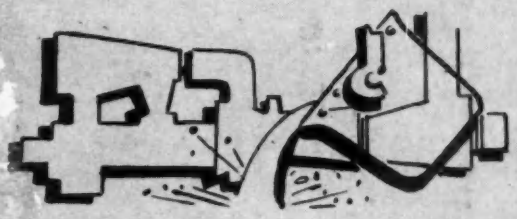
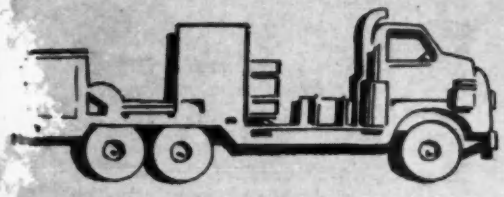
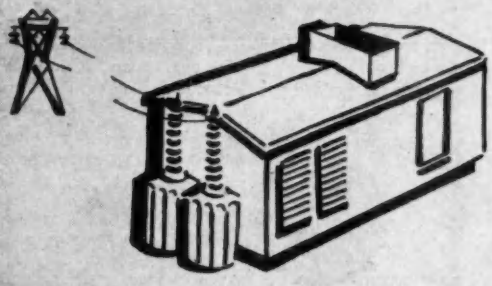
JANUARY 1960

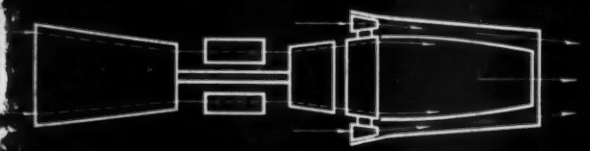
GAS TURBINE

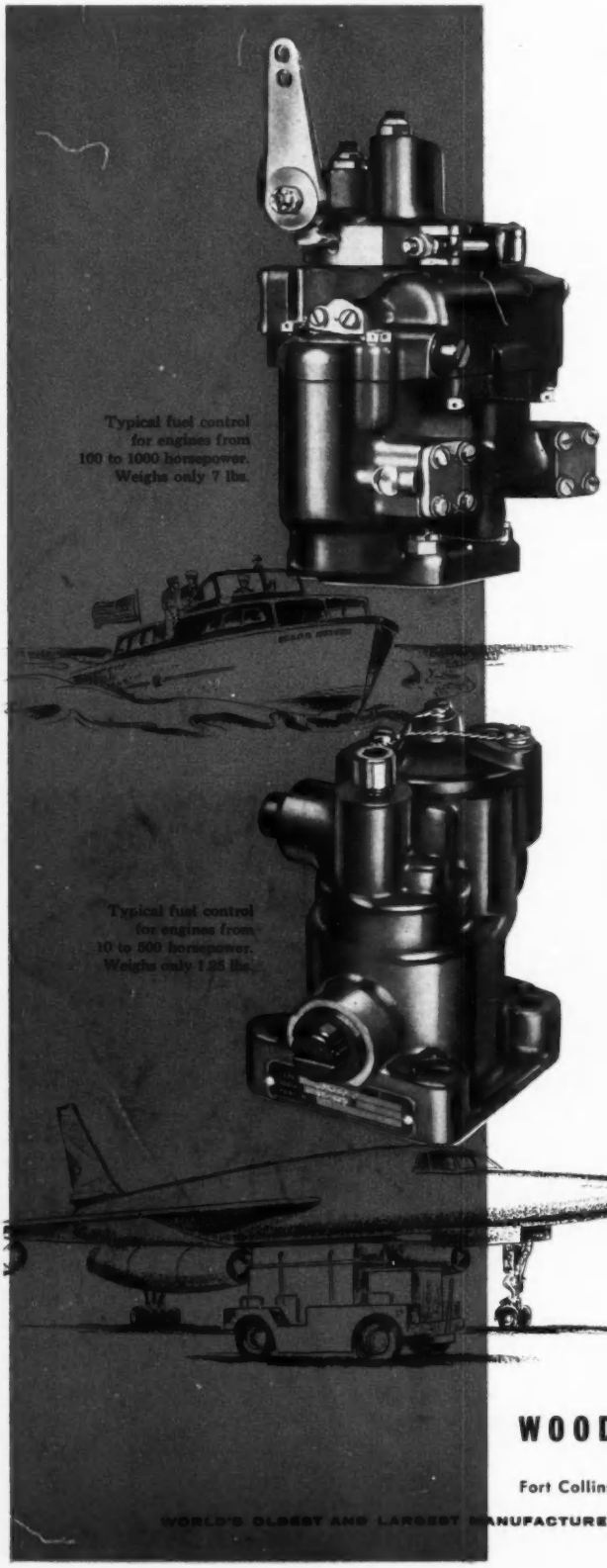












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We will be glad to send more detailed information very promptly to builders of gas turbine engines and of equipment using these modern prime movers.

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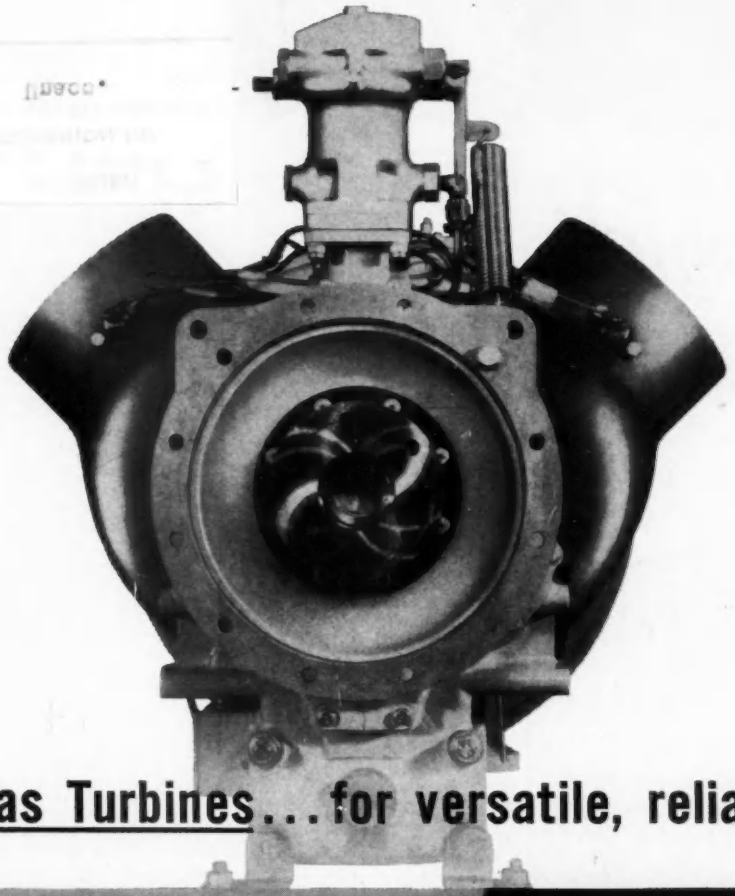
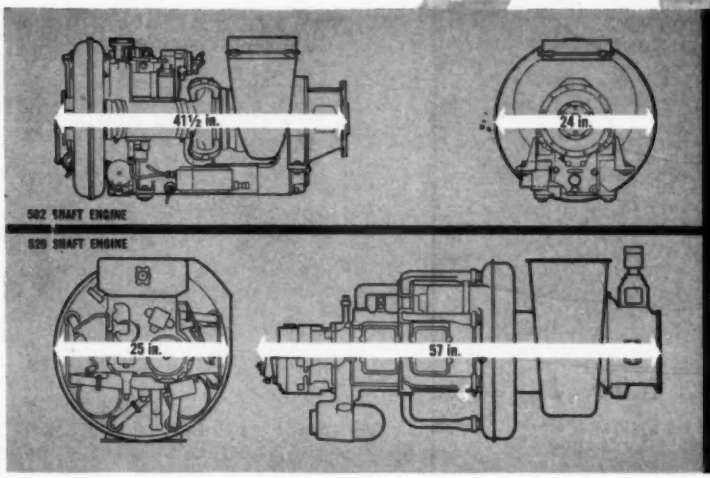


Boeing Gas Turbines... for versatile, reliable power



The Boeing 502 gas turbine is a production engine backed by eight years of service experience. In a wide variety of marine, aircraft and industrial applications, the 502 has proved itself a reliable and economical power source.

Latest shaft models, available for immediate delivery, range from a 220 h.p. model for long-life surface applications, to a 360 h.p. model for target drone application. The 502-11B powers the compressor of the Boeing TURBO-STARTER, now being used by major airlines all over the world to start the engines of turbojet and turboprop transports.

The 520 series, now under development test, retains the basic single-stage simplicity of the 502, and operates at specific fuel consumption under 0.70 lb/bhp/hr. Two series of the 520 in the 350 to 500-plus horsepower class are being developed. One is for aircraft and helicopter applications, the other for marine, industrial and special automotive applications. The 520 engine will be available for delivery later this year.

For information, call (JUniper 5-1409) or write Charles Blackburn, Industrial Products Division, Boeing Airplane Company, Box 3955, Seattle 24, Washington.

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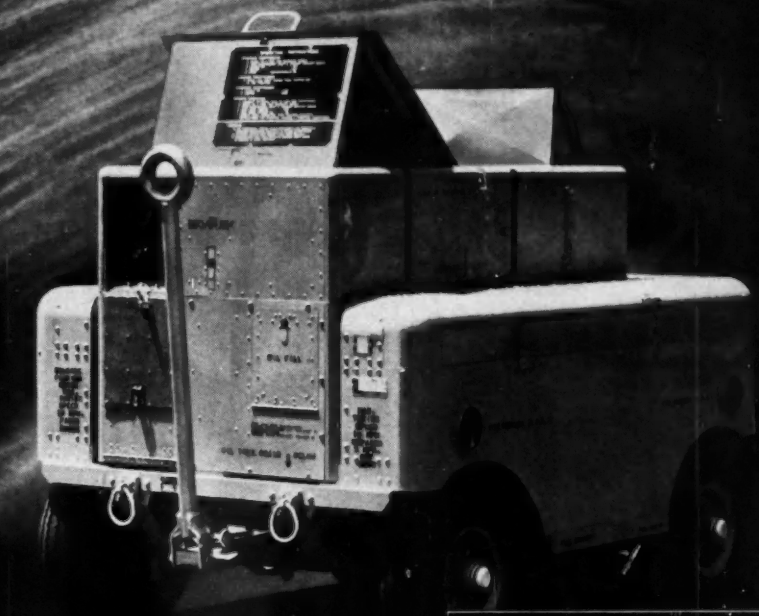
EXHIBIT SPACE IS STILL AVAILABLE

Exhibitors signed up to date include over 12 Gas Turbine Manufacturers and many Accessory Manufacturers.

Take advantage of this outstanding opportunity to present your products and services to engineers — engineers who are educated to specify and buy.

AiResearch gas turbine completes 5,000 start cycles



Reliability Record Achieved Under Tough Test Conditions

Air Force trailer-mounted MA-1A starter cart with improved AiResearch GTC 85-20 gas turbine unit.

AiResearch engineers inspecting improved AiResearch GTC 85-20 gas turbine unit after successful 5,000 start cycle test.

A world performance record for small gas turbine reliability has been established by this improved AiResearch GTC 85-20 unit... 5,000 start cycles. During each start cycle the turbine was brought to peak load twice, with a shut down time of only five minutes. This is equivalent to two main engine starts per cycle.

Throughout the entire test only routine maintenance was necessary plus replacement of one generator brush. AiResearch gas turbines now in production incorporate the improvements made in this newly tested unit.

Pneumatic power source for the Air Force's trailer-mounted MA-1A starter cart, the engine was torn down under supervision of Air Force personnel from Wright Air Development Center. It is now undergoing further tests upwards of 10,000 start cycles.

This intense product improvement in gas turbine reliability is matched only by AiResearch versatility. The world's largest manufacturer of lightweight turbomachinery, AiResearch has designed, developed and produced more than 8,500 gas turbines of all types vital to military and commercial ground support as well as auxiliary and prime power applications. Your inquiries are invited.

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U.S. Army chooses

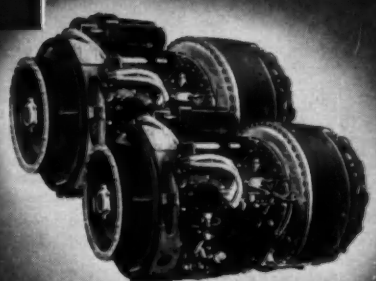
Lycoming T55

for its newest "workhorse" Vertol YHC-1B Chinook

Designed to support fast-moving combat teams of the "Pentomic" army, this 2- to 3-ton all-weather transport can carry troops, missiles or cargo in its unobstructed 30-foot-long payload compartment.

To power the Army's YHC-1B "Chinook," evaluation boards of both the Army and Air Force selected two Lycoming T55's, rated at 1940 hp each. Developed under joint Army-Air Force sponsorship, the T55 is the most powerful American free-power turbine to complete its 50-hour preliminary flight rating test.

For further information on any of Lycoming's complete line of power plants, write to: Lycoming Division, Avco Corporation, Stratford, Conn.



Lycoming T55-L-3 Gas Turbine, 1940 HP

Lycoming

Division—Avco Corporation | Stratford, Conn., Williamsport, Pa.

GAS TURBINE MAGAZINE . . . *incorporating gas turbine power*

GAS TURBINE

VOLUME 1, No. 1, JANUARY-FEBRUARY, 1960

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Great Britain	Newspaper Representations, Ltd. 231-2 Strand London, W.C.2, England
Germany	Linder Press Union GmbH. Wittelsbacher Alle 60 Frankfort/Main, Germany

Subscription Rates

	Single Copies	1 Year	2 Year
U. S.	$0.75	$3.00	$5.00
Canada	$0.75	$3.00	$5.00
Foreign	$1.50	$5.00	$9.00

Back Issues — Twice Published Rate

GAS TURBINE, published at Kutztown, Pa. by Gas Turbine Publications, Inc. Executive and Editorial Offices: 80 Lincoln Ave., Stamford, Conn. Telephone: DAvis 4-2131 Cable address: Diesel-pub, New York Volume 1, No. 1, January-February, 1960. Copyright 1960 by Gas Turbine Publications, Inc.

editorial **Purpose and Scope of GAS TURBINE . . . 7**

articles **Gas Turbines Today—A Perspective . . . 14**

Blast Furnace Blowing . . . 20

Gas Turbine Experience—The Record . . . 22

Gas Turbines for Airliners . . . 26

Gas Turbine Power Division Conference Program . . . 29

MGCR—Marine Propulsion Plant of the Future . . . 30

departments **Hot Line . . . 9**

Industry News . . . 10

Product News . . . 34

Patents . . . 36

Product Technical File . . . 39

Technical Briefs . . . 40

Advertisers Index . . . 42

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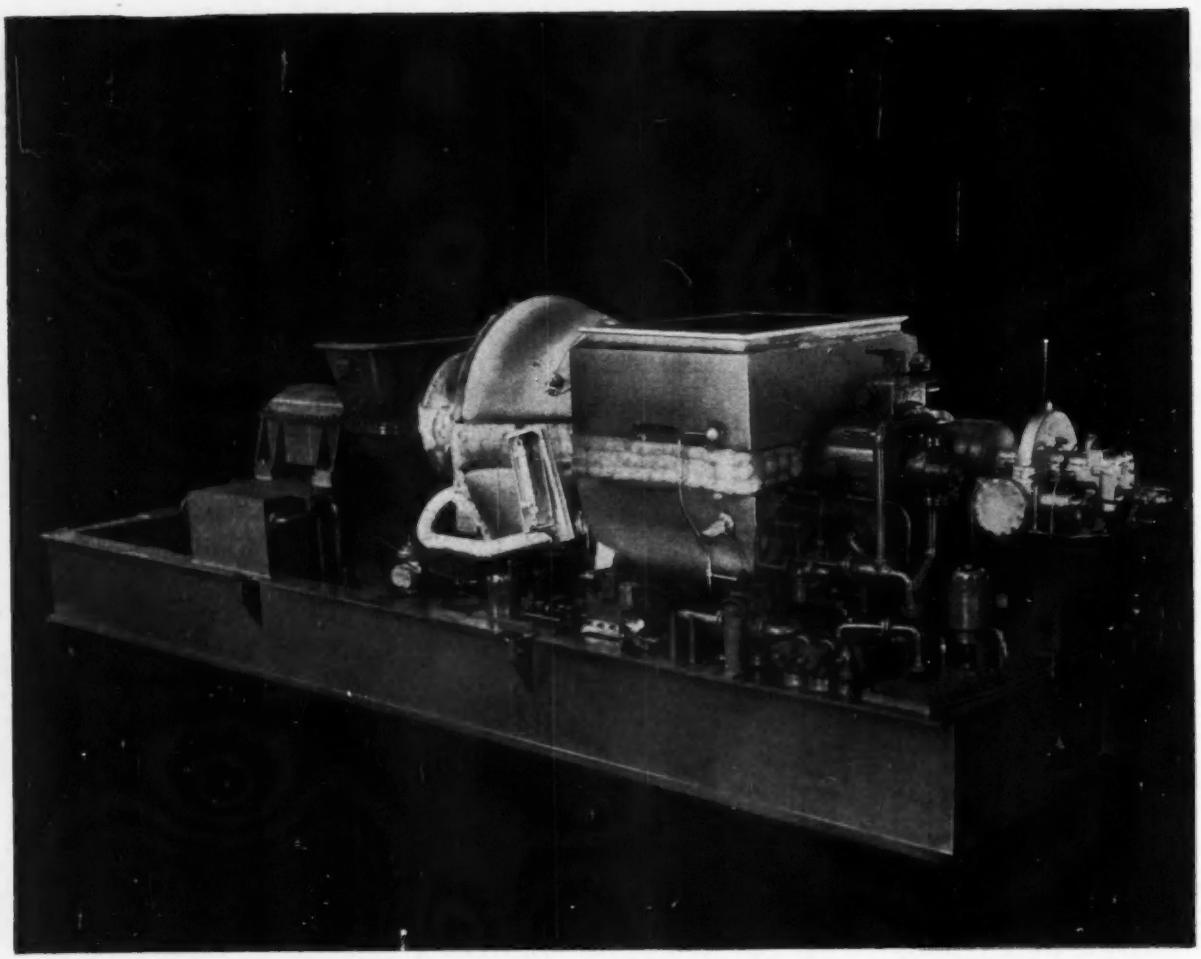
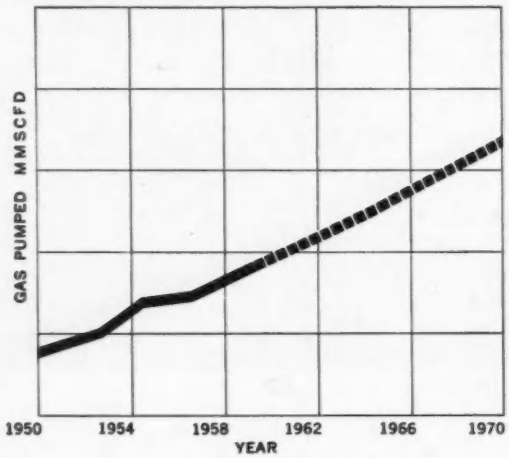


WESTINGHOUSE GAS TURBINES . . .

Engineered to help you cut gas transmission costs



Transporting the ever-increasing volume of natural gas through America's pipelines, while continuing to keep costs down, demands compressors and drives of higher capabilities than ever before.

Westinghouse gas turbines offer you a two-pronged solution to this problem:

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2. The full range of machines offered by Westinghouse lets you match the right drive to the largest compressor compatible with your line characteristics.

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GT EDITORIALLY SPEAKING

Purpose and Scope of GAS TURBINE— A Statement by the Publisher

An exciting adventure . . . Industry is now exploring new territory—commercial application of the GAS TURBINE. To keep pace with new discoveries and experiences, here is a new magazine, GAS TURBINE, reporting and interpreting so that all may read the record, keep up to date, learn and profit by the experience of others. Industry is just beginning to investigate the tremendous potential for applications of this now commercially-practical prime mover. It seems appropriate that it should have its own forum and voice—GAS TURBINE. They will grow together. Every industry needs a spokesman, an interested and informed third party between manufacturer and user, to bring developments into focus and true perspective. As this is a commercial adventure, its spokesman should be, and is, a business magazine, geared to the immediate needs of a new and mushrooming industry. It will report the latest designs, interpreting their commercial importance and impact. New uses to broaden applicational concepts, and hence sales, will be covered. Operating reports will be presented to show the practicality of these exciting new prime movers. Since commercial acceptance and costs are practically synonomous, initial, operational and maintenance costs will be covered objectively. Add to this—general industry news, business information, details of important events and digests of significant technical literature—and it shapes up as a package that every one in the industry will want and read. There's a function beyond the "forum" concept, too. It will be a market place, a common meeting ground for manufacturer and user. Achieving "togetherness" for viewpoints such as "I've got something you need" and "Who makes something that will do this?" is not only important to sales but is a real communication service, essential in a fast-moving industry. Now, who'll be shaping up the package? It will be written and edited by real "pro's" in the field; check the title page. Finally, the objective of GAS TURBINE is to serve the industry as its spokesman and to promote its growth. This magazine is for you; and to serve your needs. Let's have your comments and suggestions so that we can do an ever-better job of serving you and industry through GAS TURBINE . . . an exciting adventure.

G. Renfrew Brighton
Publisher

NUGENT DUPLEX FILTER
keeps all the lube oil clean
for this Gas Turbine

The 7000 HP General Electric gas turbine shown above is destined for service in an East Texas chemical plant. A Nugent 1555BF-4L4 Duplex Filter is an integral part of the turbine system. Each filter comprising the duplex has a capacity of 150 GPM of 125 SSU viscosity lubricating oil. All the oil in circulation is filtered every cycle before going to the bearings. Foreign solids as small as 5 to 10 microns are removed; thus, harmful impurities cannot reach vital parts to accelerate wear.

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Assignments are available in the turbo machinery field of research, design, development, performance analysis, test and applications of gas turbines and components for air, surface and marine use. Requirements are a BSME or higher degree, plus five or more years of applicable experience.

Other outstanding positions are open for engineers with a BSME or higher degree, plus ten or more years of experience in high speed gear box design and familiarity with production methods.

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Seattle 24, Washington

BOEING

GT HOT LINE

HARVESTER MAY BUY SOLAR IN AIRCRAFT STOCK DEAL

International Harvester is moving to take over Solar Aircraft through a stock exchange arrangement. This news follows hard on the heels of Solar's purchase of 17 percent of its own stock back from Fairbanks-Morse for some 2.7-million dollars. Move would put Harvester, concerned primarily with farm equipment and heavy truck manufacturing, into competition with GM's Allison Division's gas turbine. It also puts a temporary end to Fairbanks-Morse bid to enter gas turbine field.

CHRYSLER'S CROSS-COUNTRY GAS TURBINE RUN ANNIVERSARY

Just a year ago, Chrysler put its gas turbine-powered Plymouth in a comparison test with a standard Plymouth on a Detroit-New York run. In case you missed it, here's the performance turned in by the gas turbine-powered car: Detroit to New York, load factor less than 25 percent – 19 mpg; New York to Detroit, maximum load without exceeding speed limits – 17 mpg. One interesting finding . . . in traffic, gas turbine economy was equal to or better than for conventional engine. Chrysler is getting closer

MODULATED GENERATOR – NEW DIMENSION IN ELECTRICAL POWER

Generators operating at turbine speeds! Multi-polar, high-speed . . . both factors promising smaller size, lower weight, less cost. Several firms reported as developing these a-c generators for direct drive at 10,000 rpm or more. An electronic "bag of tricks" converts output to a desired 60 or 400 cycles.

REAL PROGRESS IN GAS BEARINGS

Use of gas bearings in gas turbines is well beyond dreamer stage. Definite progress was shown at Navy R & D and Franklin Institute's Gas Bearing Symposium in Washington last November. Advantages are obvious and apparently techniques are moving toward practicality.

POWERS-PEAKING – A DEVELOPING GAS TURBINE MARKET

Large gas turbines, 5000-hp and up, are getting the nod for peaking service. Small size and low weight make them a "natural" for supplying extra power to back up base-load units. They're going into central power stations in various countries. Also, they're finding acceptance in naval service . . . providing extra power for flank speeds, high-speed maneuvering. British and West German Navies are big for this method to boost cruising speeds.

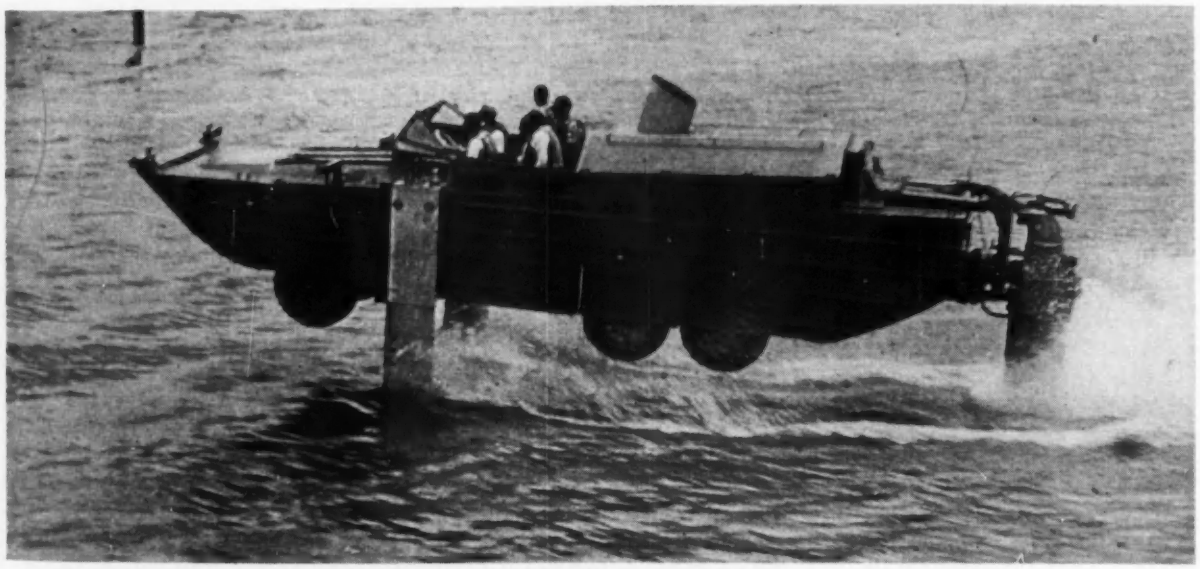
ARMY'S OVERLAND TRAIN HAS FOUR GAS TURBINES

Le Tourneau's overland train being built for Transportation Corp. gives train load capacity without track limitations. Hauling heavy loads over all kinds of terrain takes power – 4000 hp. Three 1100-hp Solar gas turbines handle propulsion, a 700-hp unit supplies auxiliaries with power.

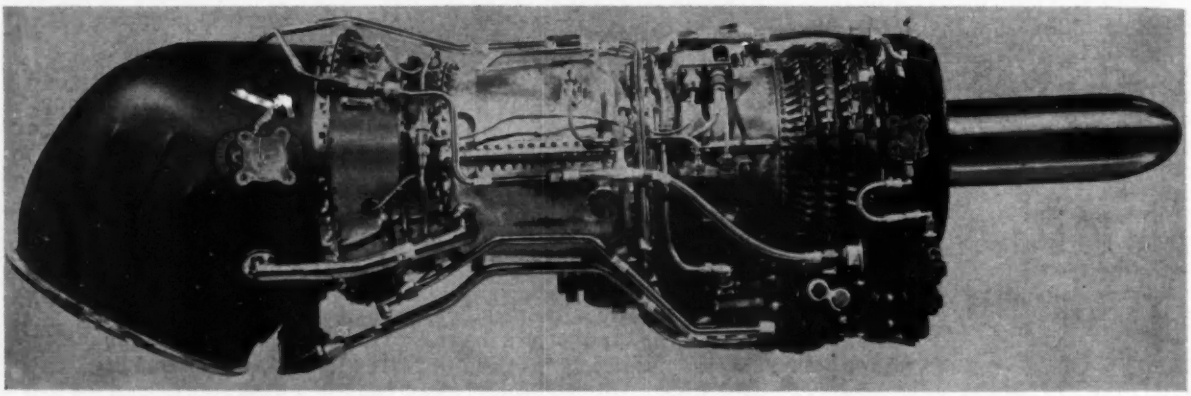
JET TRIED AS SNOW BLOWER

New York Central put a modern jet in a caboose for test as a snow blower. Object is to reduce cost of snow removal in a freight yard. Swiveled on back of caboose, the jet's blast is reported to blow snow and ice from tracks and switches for 100 ft or more.

GT INDUSTRY NEWS



Army Ordnance Corps' DUWK or "Duck" has matriculated to the "Flying Duck", thanks to hydrofoils and gas turbine power. It first "flew" in August, 1959, at Miami Shipbuilding Corporation's test site. AVCO Corporation's Lycoming Division has the Army-sponsored project for both hydrofoil development and also the T53 860-hp gas turbine used. Miami Shipbuilding is handling the construction work under sub-contract from Lycoming. Objectives were to demonstrate feasibility of both hydrofoils and gas turbine power for this vehicle, grossing 26,000 lb. Result? In "flight" on two hydrofoils forward, one aft, speeds to 50 mph were obtained. Excellent stability is maintained through automatic foil control.



General Electric's T58 aircraft gas turbine shown will have a new designation when it enters industrial service. According to the company's Small Aircraft Engine Department at Lynn, Mass., the industrial version operating on liquid fuel will be called the CG720-1 and the version for natural gas operation will be the CG722-1. This 720 series engine will have a maximum output guarantee at sea level of 1050 shp. It weighs just 271 pounds. Developed originally for the Navy, the T58 underwent an intensive 6-year development program before it was felt ready for introduction of industrial versions.

Reliable Ground Support with Gas Turbines

Another step in evolution of the gas turbine engine as a reliable, efficient power source was made evident recently with purchase by Sperry-Salt Lake of a number of small gas turbine generators for ground support of the U. S. Army Sergeant missile. The gas turbine generators are manufactured by The Garrett Corporation's AiResearch Phoenix Division.

A turbine unit will power the launchers' electrical and hydraulic systems and another unit will supply power to the electronic checkout van, with the generators furnishing 400-cycle power. Field tests of the gas turbines established extreme reliability under all environmental conditions including desert dust and heat, salt spray and arctic cold. Other features were low fuel consumption, low noise level and growth potential.

AiResearch at Phoenix is the world's largest producer of small gas turbine engines. Developing the first small jet engines in 1946, the Arizona firm now has close to 9000 units operating in the field in various configurations as compressor or generator units for aircraft ground support, airborne auxiliary power or helicopter propulsion engines.

Gas-Cooled Reactor Symposium Scheduled for February

An important "first," a symposium on gas-cooled reactors (combined nuclear reactors and closed-cycle gas turbines) is announced by The Franklin Institute and The American Nuclear Society, Delaware Valley Section. It is to take place at The Franklin Institute in Philadelphia, Pa., on February 10-11, 1960.

Three sessions will discuss: Status of Major Programs; Fuel Elements and Materials; and Components and Loop Studies. Several papers by authorities are scheduled for each session. The tentative program states that France, Australia, Germany and USSR have been invited to participate; the United Kingdom is already well represented. In addition to British papers, Sir William Cook, C.B., UKAEA, as speaker at the Banquet, will discuss "Gas-Cooled Reactor Development in the United Kingdom."

Attendance at this international meeting is limited to 400 persons. Advance Registration through the Program Secretary, E. H. Nelson, Franklin Institute, 20th and Parkway, Philadelphia 3, Pa. is recommended. Fee to Institute and ANS members is $35 to attend all sessions, luncheons, reception and banquet and for a copy of the proceedings; $10 for reception and banquet only. Fee for non-members is $40 and $15 respectively.

Proceedings will be published by The Franklin Institute and are expected to be ready for distribution in June, 1960. Preprints of Symposium papers will not be available before or at the meeting. Better attend.

Boeing Plans Vertol Acquisition

Through the proposed merger with the Vertol Aircraft Corp., Boeing will have broadened its applicational area into an important field-short haul and commuter-type aircraft. This will complement its present long-haul aircraft capability.

The STOL/VTOL field promises to be a major market as fast airport-to-city transportation is essential for full utilization of increased long-haul speeds. If the merger goes through, Boeing will have both the capability and the outlet to serve this market. Their present line of turbines, field-proven to be rugged, are well suited for this type of service.

Aerial Utility Vehicle Gets Gas Turbine Power

The Army has ordered from Piasecki Aircraft Corporation a new gas turbine-powered aerial utility vehicle (59-H) with higher performance than the prototype powered by a piston engine. Piasecki says the new vehicle will not be a "ground effect" machine which rides on a cushion of air, but can achieve free flight above the ground cushion. Two 425-eshp Artouste II-C gas turbine units will be used.

Helicopter Airline Picks Gas Turbines

Los Angeles Airways, the world's first scheduled helicopter airline, purchased five twin gas turbine-powered Sikorsky helicopters. This power selection is significant in view of their experience. It is also noteworthy that Sikorsky Division of United Aircraft Corp. is moving into the field of gas turbine power for their products.

Eastern Airline Selects AiResearch Starting Units

Eastern Air Lines picked AiResearch turbines for their jet starting units. These are a multipurpose gas turbine power unit for starting of main engines, electrical power and for ground cooling and heating of Eastern's new Electra turboprop fleet.

AiResearch's versatile ground support equipment is tailored to meet the requirements of the rapidly expanding commercial airline fleets of new turbine-powered airliners, military aircraft and tactical missiles.

GT "COMING UP" REMINDER

JANUARY 11-15 Society of Automotive Engineers Annual Meeting with Display, Sheraton-Cadillac and Statler Hotels, Detroit, Michigan.

JANUARY 18-19 American Society for Testing Materials Committee A-1 on Steel, Hotel Warwick, Philadelphia, Pa.

JANUARY 25-28 Institute of the Aeronautical Sciences Twenty Eighth Annual Meeting, Hotel Astor, New York, N. Y.

JANUARY 26 The Institute of Marine Engineers, Joint Panel on Nuclear Marine Propulsion (Paper "Control and Instrumentation of Marine Reactors"), The Memorial Building, 76 Mark Lane, London, E. C. 3, England.

FEBRUARY 10-11 Franklin Institute and Delaware Valley Section of the American Nuclear Society, Gas Cooled Reactor Symposium (one session devoted to components, including rotating machinery), Franklin Institute, Philadelphia, Pa.

FEBRUARY 15-18 Annual Meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., Sheraton-Atlantic Hotel, New York, N. Y.

MARCH 6-9 American Society of Mechanical Engineers, Gas Turbine Power and Hydraulic Divisions Conference and Exhibition, Rice Hotel, Houston, Texas.

MARCH 10-11 Institute of the Aeronautical Sciences, Flight Propulsion Meeting (Classified), Cleveland, Ohio.

MARCH 14-15 American Society of Mechanical Engineers, Lubrication Symposium, Engineering Societies Building, New York, N. Y.

MARCH 15-17 Society of Automotive Engineers, Automotive Meeting, Sheraton-Cadillac Hotel, Detroit, Michigan.

MARCH 22-24 Society of Automotive Engineers, Production Meeting, Statler Hotel, Cleveland, Ohio.

New High-Strength Nickel Alloy Steels

The International Nickel Company has confirmed reports in the trade that a remarkable new family of very high-strength nickel alloy steels has been invented in their Research Laboratories.

Nominally identified as 25% nickel steels they have 2 to 6% titanium and/or aluminum; carbon held as low as possible and preferably below 0.05%; silicon and manganese, normal; and the balance iron. These new alloys achieve unique properties by simply air-cooling from the heat-treating temperatures. Yield strengths in excess of 250,000 psi with 6 to 10% elongation and above 20% reduction of area are obtainable in section thicknesses where such properties were not heretofore attained. Maximum hardness in excess of 67 Rockwell C has been obtained.

High strength properties obtained without liquid quenching means that intricate parts can be fabricated to close tolerances while the steel is in its soft annealed condition and can be hardened to these high strength levels without appreciable distortion. This, together with the high order of mechanical properties attainable, should make the 25% nickel steels of particular interest for aircraft and missile applications and for high-strength, wear-resisting precision parts such as bearings.

The 25% nickel steels are readily hot worked and can be produced in all the various commercial shapes—bars, plate, sheet, tubing, etc. While not yet commercially available, it is expected that ultimately they will be produced by a number of steel producers. This family of new steels, which is covered by a U. S. patent application of INCO, was invented by C. G. Bieber, Research Metallurgist of the INCO Research Laboratories.

Low-Horsepower Gas Turbine for Broad Application

Sam Williams, president of Williams Research Corporation recently announced development of a 75-hp turbine, built with and without regenerator. With regenerator, the unit would have an economy almost as good as most piston engines.

This small company, with its unusually fine know-how on turbines, should be watched. The unit is well suited for use in not only marine and automotive equipment but is especially suited for small aircraft.

Anderson Chairman of GTP Div., ASME

New Chairman of the Gas Turbine Power Division of the ASME is J. Hilbert Anderson. Those who have been active in any of ASME's technical divisions know the importance of competent, energetic leadership. GTP has been very fortunate in this regard and Mr. Anderson follows in the tradition.

He brings a wealth of background to the job. Educated at Pennsylvania State College, he received his BS in Mechanical Engineering in 1930 and his MS in 1933. This was followed by 18 years with Ingersoll-Rand, nine years of which was in charge of research in the fields of compressors, internal combustion engines and steam turbines.

Since 1952 he has worked at York Corporation as Engineering Manager of Centrifugal Compressors and for the past year as Chief Engineer of Machinery Products.

He has been an ASME member since 1945 and in addition to his present work as GTP Chairman, he is an active member of Power Test Code Committee No. 10 on Centrifugal and Axial Compressors. He holds many patents and has written many published articles on technical subjects.

Flame-Plated Coatings for Seal Improvement

A new development shows promise of improving seal performance and increasing the range of conditions under which they will operate. Linde's Flame-Plating process provides materials for accomplishing these objectives. These materials will operate at extreme temperatures (−400°F to +1600°F) with little or no lubrication.

A few of the many proven items include:

(1) Actuator shafts Flame-Plated with tungsten carbide for mating with interference-fit metal "O" rings.

(2) Hot gas turbine seals operating at 1200°F.

(3) Face seals operating under a variety of conditions including the sealing of cryogenic liquids, hot gasses, various hydrocarbons, acids, abrasive slurries, etc.

(4) Turbine engine shaft seals operating at 800°F.

Features of the process are unusually strong bond and low base-metal temperature (400°F) during coating deposition to prevent loss of heat treatment or distortion. The tungsten carbide, chromium carbide and aluminum oxide coatings are resistant to wear, abrasion, and fretting corrosion even at high temperatures. They can be ground and lapped to 1 microinch rms finish.

Lear Moves into Non-Military, Non-Aircraft Field

Appointment of two manufacturer's representatives to handle Lear, Incorporated commercial-industrial products was announced today by T. K. Greenlee, General Manager of the Electro-Mechanical Division.

Named were Berndt Associates of Glencoe, Ill., and Electro-Mation Associates of Warren, Mich.

Their selection is part of Lear's recently-announced diversification program into the non-military and non-aircraft field, Greenlee said. Products they will handle initially include the Leartron Positioning System, a highly-precise 60-cycle, remote positioning system, and electric, hydraulic and pneumatic industrial actuators.

Berndt Associates will cover the states of Wisconsin and Illinois and the Gary, Ind., area. Electro-Mation Associates will cover Michigan and the Toledo, Ohio, area. Lear's program calls for retaining representatives also in the New England area, New York City-New Jersey area, Philadelphia and Pittsburgh, Pa., Los Angeles, Calif. and other major industrial sections in the United States.

Turbojets Needed for Helicopter Blade Tip Power

Hiller Aircraft Corporation has made the statement that for large heavy cargo-crane helicopters—"to satisfy all major design criteria, tip (of the blade) power must be used —and turbojet engines must supply that power." This gives a high payload-to-gross weight ratio. Heavy and complex gear trains are eliminated. Turbojet engines provide the range and low fuel consumption rates needed to make tip power economical.

AiResearch "Hound Dog" Turbine Starter

"Hound Dog", the air-to-ground missile carried by the B-52 bomber, is started by a specially-designed air turbine probe starter developed by The Garrett Corporation's AiResearch Phoenix Division. Produced by the Missile Division of North American Aviation, the "Hound Dog" is carried in pairs under the bomber's wing. When within several hundred miles of the target area, it becomes self-propelled by its own J-52 engine and is directed to the target by its navigation system.

Although capable of start-up when airborne, the missile's engine is started on the ground by the AiResearch starter to operate as a booster engine for the bomber during taxi and takeoff. Its added thrust more than makes up for its weight and drag.

Boeing Turbine Service Increased

Boeing Industrial Products Division is stepping up its gas turbine service program with assignment of the following field service representatives: Warren Wheeler at Los Angeles; Bernard Sternke at Seattle; Jim Schubert at Chicago; John Crowley at Miama, Florida; and Harley Bowdish at New York.

These men will service all small Boeing gas turbines in their areas including the 320-lb, 240-hp small gas turbine (502-10C) and its 205-air hp turbine-driven compressor counterpart (502-11B) used in the Boeing Turbo-Starter jetliner ground support unit. These turbines are in international use. Also trained in servicing these units are 45 Boeing Transport Division representatives stationed throughout the world on the 707 Jet Stratoliner program.

GT CONTRACTS PROCUREMENTS

Some gas turbine procurements initiated and contracts awarded during recent months by various agencies of the U. S. Government are listed. This material is from the U. S. Department of Commerce publication "Synopsis of U. S. Government Proposed Procurement, Sales and Contract Awards."

1. Middletown Air Materiel Area, USAF Olmstead Air Force Base, Pa. Overhaul of J-65 Engines—$4,967,115—Curtiss-Wright Corp., Wood Ridge, N. J. Negotiated procurement.

2. Navy Purch. Office, Washington, D. C., Turbo Jet Engine Run-up Test System Equipment, portable, universal Model NER-3, 29 ea; Spare Parts Provisioning Data, 1 set; Reproducible Mfg. Dwgs, 1 set; Publications, 1 lot; Data Sheets, 1 lot—(N600)(17)-52497(IFB600-2247-59)— $927,219—Air Logistics Corp., 3600 East Foothill Blvd., Pasadena, Calif.

3. Dept. of the Navy, Bureau of Aeronautics, Washington, D. C. Services and materials to convert two (2) J57-P-43WB Mockups to TF-33-P-3 Mockup configuration. NOas 59-8068-f (PD-41-3914-O)—$70,000—United Aircraft Corp. (Pratt & Whitney Aircraft Corp.), East Hartford, Conn.

4. Okla. City Air Mat. Area, USAF, Tinker AF Base. Overhaul of J47-GE-25/25A Aircraft Engines, (RFP-OC-0-02A-0056)—Job—$1,743,443—Curtiss-Wright Corp., Utica Division, Utica, Mich. This was a competitively negotiated procurement. Two bidders were solicited and 2 bids received.

5. Okla. City Air Mat. Area, USAF, Tinker AF Base. Overhaul of J73-GD-3D/3E Aircraft Engines. (RFP-OC-0-02A-0088)—Job—$463,908—Curtiss-Wright Corp., Utica Division, Utica, Mich.

6. AMC Aero Systems Center, Wright-Patt. AF Base, Ohio. 8 each J79-GS-9 Turbojet Aircraft Engines for B58 Test Program. (PR EP-9-2840-4917)—$1,305,000—General Electric Co., Flight Propulsion Division, 1 Jimson Road Cincinnati 15, Ohio.

7. Department of the Navy, Bureau of Aeronautics, Washington 25, D. C. Sixty Air Turbine Starters, Contractors' Part No. 36E62-2A to be furnished in accordance with Specification MIL-S-19957A(Aer). Noas 59-0302-f (PD-42-2150-59)—$109,680—Bendix Aviation Corp., Utica Div., Utica, N. Y.

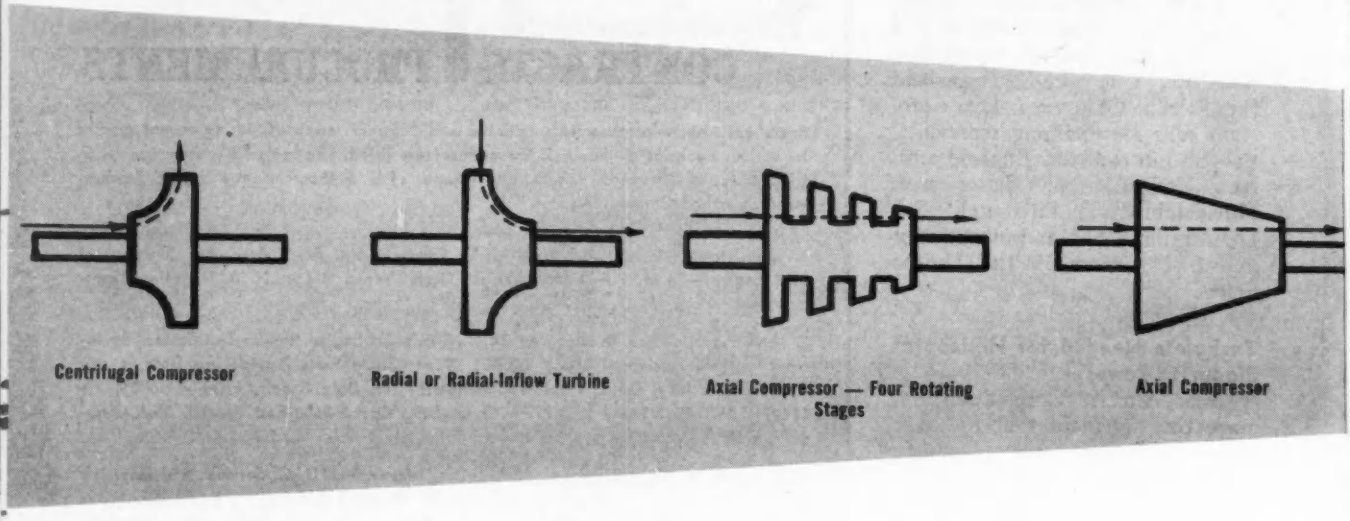
8. Oklahoma City Air Materiel Area, U.S.A.F. Tinker Air Force Base, Okla. Major and Minor Overhaul and/or Minor Repair of YJ/J79-GE-1/3A/5/7 Aircraft Engines. (RFP OC-0-02A-0377)—Job—$1,382,543—General Electric Company, Cincinnati, Ohio.

9. Oklahoma City Air Materiel Area, U.S.A.F. Tinker Air Force Base, Okla. Overhaul of J47-GE-23/25/25A Aircraft Engines. (RFP OC-0-02A-055 and 56)—Job—$1,768,620—General Electric Co., Cincinnati, Ohio. This was a competitively negotiated procurement. 2 bidders were solicited and 2 bids were received.

10. Oklahoma City Air Materiel Area, U.S.A.F., Tinker Air Force Base, Okla. Overhaul and/or Repair of J-33-A-35/J33-A/37/J33-A-44/J33-A-10/J33-A-20 and J33/24A engines (RFP OC-0-02A-004)—Job—$2,932,606 Southwest Airmotive Co., Love Field, Tex.

11. Warner Robbins Air Materiel Area, U.S.A.F., Robbins Air Force Base, Georgia. Spare Parts for MA-1 Gas Turbine Compressor (RFP-59-1680)—$35,343—Continental Aviation and Engineering Corp., Toledo, Ohio.

GAS TURBINES



Centrifugal Compressor

Radial or Radial-Inflow Turbine

Axial Compressor — Four Rotating Stages

Axial Compressor

THOUGH the gas turbine industry is only in its teens the first patent was taken out 169 years ago. A lot has happened since then, mostly in the past ten years, and the tempo of development is increasing steadily. Let's look back only ten years and see where we were at that time.

Boeing Airplane Company was producing its initial units including jets, turboprops and the "502" for marine and many other services.

Brown Boveri Corporation (and Allis-Chalmers) had many of the low-temperature Houdry units in service in the U.S.A.

Carrier Corporation (Elliott Company) was building experimental units.

Curtiss-Wright Corporation was producing jet units then—and still is.

Dresser Industries (Clark Brothers Company) started to build their first unit for the Tennessee Gas Transmission Company.

The Garrett Corporation (AiResearch Manufacturing Company) had gone into the business of gas turbines to drive aircraft auxiliaries, a wise start.

General Electric Company was already in the jet, turboprop and heavy gas turbine business.

General Motors Corporation (Allison Division) was producing several sizes of turbojets and experimenting with other units.

Solar Aircraft Company had built the experimental twin AAP-80 auxiliary power unit, the fore-runner of its present line.

Thiokol Chemical Corporation (Reaction Motors Div.) was building liquid rockets requiring gas turbines to drive the accessories. Jimmy Wyld was an ardent believer of building a good gas turbine. He referred to it as the "heart" of the rocket. Many still remember "Jimmy" as remarkable in his field.

United Aircraft Corporation (Pratt & Whitney Aircraft Division) was already in the turbojet business.

Westinghouse Electric Corporation was already building turbojets and was also in the heavy turbine business.

Today is quite different; now let us see who has gas turbines in the US or is actively selling them in this country. Those listed include the major builders. The many others who are now experimenting indicates that the list of builders should double within the next ten years.

1. AEROJET-GENERAL CORPORATION
Turbo-Machinery Division

This company has greatly expanded since I first visited Azusa when Bill Gore took me through its plant. In those days the principal product was solid propellents. Today they have a Turbo-Machinery Division which not only handles the design of their rocket turbines for control and pumping liquids but also others for special uses. This company is using the gas turbine wherever it fits into its line of products.

2. AVCO MANUFACTURING CORPORATION
Lycoming Division

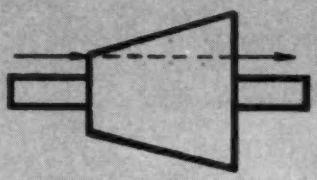
Lycoming Division is an old company in the airplane piston-engine business. It is now producing two basic gas turbines, primarily for aircraft, but which are also finding uses in marine and other fields.

The T53 ranges in power from 600 to 1000 hp at the shaft. The T55 runs in power from 1100 to over 2000 hp. Both turbines are of a similar design and both have a separate turbine.

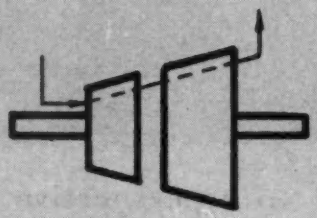
....a perspective

by R. Tom Sawyer

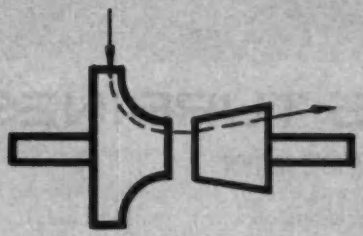
A resume of gas turbine producers and their products. Included are American-built products and those units and designs from abroad actively being marketed here.



Axial Flow Turbine



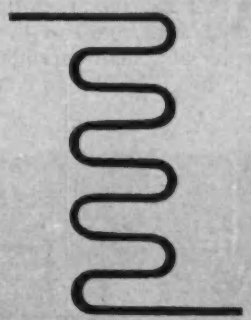
Split Turbine — Axial Flow



Split Turbine — Radial and Axial Flow

Combustor

Heat Exchanger — Intercooler or Regenerator



Heated Coil for Closed Cycle

3. BELL AIRCRAFT CORPORATION

There are several companies like Bell that make and design their own gas turbine units for certain rocket aircraft auxiliary use.

4. BOEING AIRPLANE COMPANY

This company was one of the first in the small turbine business. It has been said that they have probably made turbines for more types of application than any other organization. Their list of "firsts" is amazing; ranging from boats to power plants; trucks to locomotives; helicopters to small airplanes.

The "502" turbine, their main production unit, is of the split-shaft type and is normally rated 240 hp. For certain aircraft service the rating exceeds 300 hp.

The "520" turbine is their largest size and is also of the split-shaft type—the compressor turbine being of radial inflow design. Power range is 375 hp. for normal rating, up to 500 hp. for special uses.

5. BROWN BOVERI CORPORATION, NEW YORK

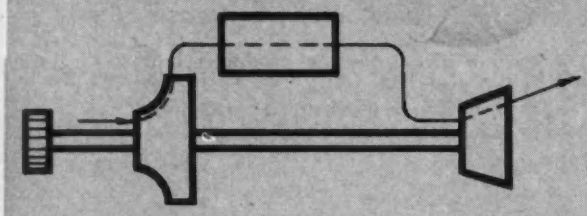
This company has a large number of gas turbines in processing and other-than-power generation service in the US. They do have several large power-generating turbines in other countries on this side of the Atlantic. This company was one of the very first to proclaim—and prove—the many advantages of the combustion gas turbine.

6. CARRIER CORPORATION

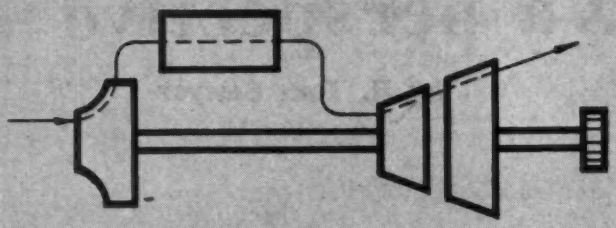
Elliott Company

This company is an old line producer of turbochargers. From turbocharger designs that have been materially changed, several turbines have been produced and now are in use in the process industry.

This company has an experimental turbine for power production on test. Rating is about 400 hp. The proposed range of turbines goes up to approximately 2000 hp.



Simple Open Cycle



Open Cycle with Split Turbine

GAS TURBINES .... a perspective

7. CHRYSLER CORPORATION

Chrysler was one of the first automotive manufacturers to build and operate a small turbine. It has undergone a tremendous amount of development and refinement. However, probably because of the stringent requirements for light vehicular service, it has not yet been put into production. Recently Chrysler has been trying their turbines out in Plymouth autos. These have been driven from coast to coast as well as on other demonstrations to prove out their economy and performance.

Chrysler's design includes a rotary regenerator. They have gone into the unknown to produce inexpensive turbine materials. It still looks as if it would be a long time before the Chrysler unit gets into production, especially as Chrysler's aim is to produce the unit for a cost competitive with the piston engine. It already has a better fuel consumption than Chrysler's conventional gasoline engine.

8. CONTINENTAL MOTORS CORPORATION
Continental Aviation and Engineering Corp.

Continental has a fine plant specifically for the purpose of building gas turbines, primarily for jet, helicopter and ground-support use.

The design is basically adopted from the French Turbomeca and has a unique method of spraying fuel into the annular combustor by pumping it in through a hole in the center of the compressor-turbine shaft.

Their J69 jet units range from 1000-lb thrust to 2000-lb thrust. Helicopter and shaft turbines are rated between 400 and 500 hp. They also do considerable business in air compressor jet-starting units, now with the model 141.

9. CURTISS-WRIGHT CORPORATION

This company has produced the J65 jet unit, with and without afterburner. With afterburner it produces over 10,000-lb thrust. Without afterburner the jet thrust is over 7000 lb. These units have been performing well in military planes.

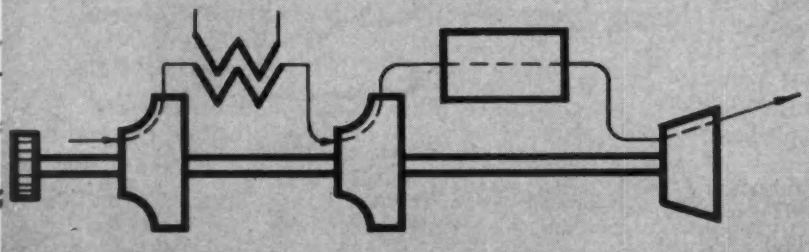
The Utica Division is developing a turbine for the Navy which has a rating between 3000 and 4000 hp. The gas-producer portion has been completed and has an excellent efficiency.

This Division is also selling the Rover turbine, primarily for fire-pump and generator use. The Rover turbine equipped with heat exchanger will make an efficient unit. While speaking of the Rover unit it should be mentioned that Utica Bend has rights to this turbine except as an automotive unit; no doubt due to Rover wishing to be first to bring out this unit in a commercial auto.

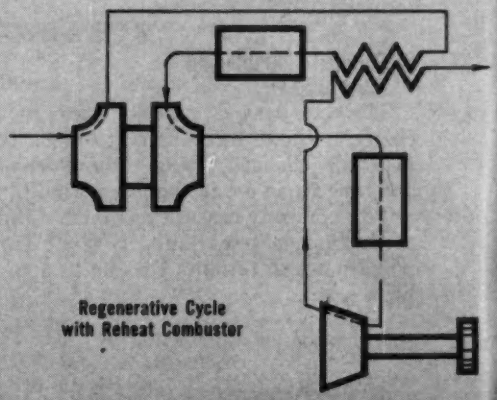
On the West Coast, Propulsion Research Corp., a Division of Curtiss-Wright, is building the "Turbo-Mite", a very small 7-kva generator set, so light weight it can easily be carried by military troops.

10. DRESSER INDUSTRIES
Clark Brothers Company

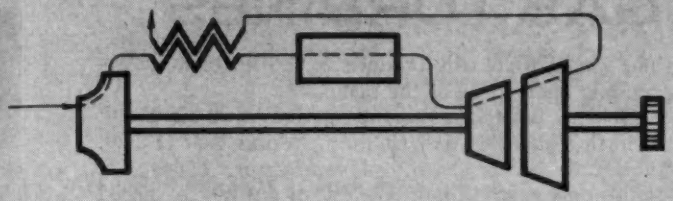
Clark Brothers Company has, for some years, produced a heavy-duty gas turbine with and without heat exchanger. Rating of this turbine is approximately 9000



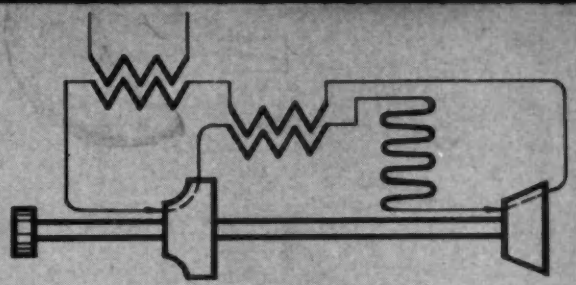
Two-Stage Compression with Intercooling



Regenerative Cycle with Reheat Combustor



Regenerative Cycle



Closed Cycle—External Heat Source

hp depending upon its application. This turbine has been used for power generation or industrial application. Ruston-Hornsby's turbine is being handled under license by Clark Brothers. Over 100 of these turbines have been sold in many parts of the world by Ruston-Hornsby. Clark Brothers already has several of these units in service in this country. This unit is rated over 1200 hp. Rating of this turbine, or any other, is reduced when a heat exchanger is applied. In this case the TA rating is somewhat over 900 hp. and a much better efficiency is achieved.

Both Clark Brothers turbines are of the heavy-duty long-lasting type, well suited to many industrial applications.

11. FORD MOTOR COMPANY

Ford is concentrating on development of automotive turbines. They have built several development units of the non-regenerative type. Then in the past few years they have developed a unit, now on test, which fundamentally consists of the standard type of split turbine which, when turbocharged, produces a compression ratio of 16 to 1. Heat exchanger and intercooler are incorporated into this compact unit.

This Ford 300-hp. unit will be carefully watched by all interested as tests show that its efficiency is equal to that of the diesel.

12. THE GARRETT CORPORATION

AiResearch Manufacturing Company Div.

This company is in the small gas turbine business and is known as the largest producer of gas turbines in the world, having built over 8000 units. Garrett is also one of the largest builders of turbochargers.

Power range is roughly 30 to 300 hp. The smallest unit is a single-shaft gas turbine. Most of the units are either airborne air compressors or generator units. Many ground-support units are furnished by AiResearch consisting of starting units, air-supply units or generator sets.

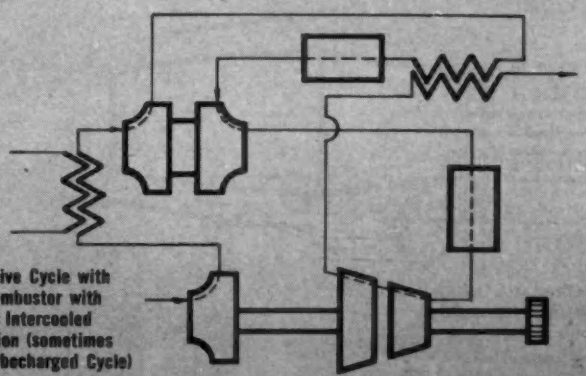
Practically all are built on the basic AiResearch design of having an air compressor of sufficient size to give sufficient excess air for useful purposes such as driving a power turbine with or without preheating; for air supply to accessories in the plane; or for cabin-pressure charging with air that passes through a heat exchanger to heat or cool it for use by the passengers.

Most of these units operate at or near maximum speed and, therefore, their design brings the best efficiency at these speeds. Radial compressors and turbines are used which are ideal for the range of 30 to 300 hp.

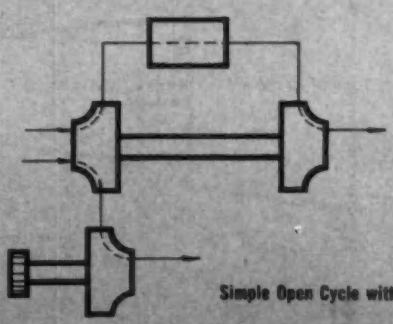
In back of the Garrett gas turbine production is an extensive research laboratory. In it, we can rest assured, future gas turbine are now being perfected for many uses.

13. GENERAL ELECTRIC COMPANY

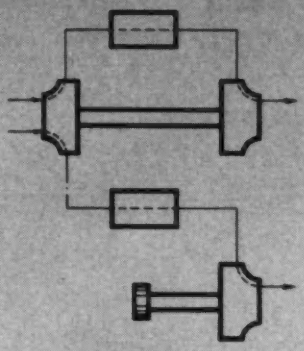
General Electric of all manufacturers probably builds the greatest variety of gas turbines. Power range is from the "T-58" of around 1000 hp. up to the largest stationary unit of over 30,000 hp. In between this range are turbines built for driving liquid rocket accessories and jet units (including nuclear) up to 16,000 lb thrust.



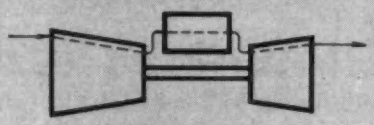
Regenerative Cycle with Reheat Combustor with Two-Stage Intercooled Compression (sometimes called Turbecharged Cycle)



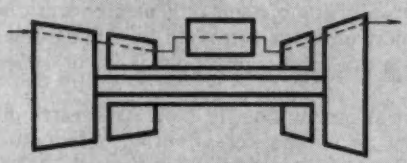
Simple Open Cycle with Air Turbine



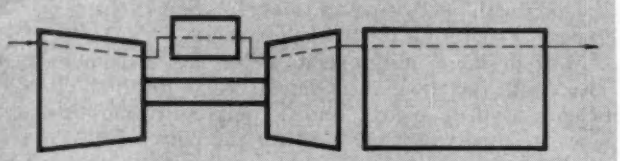
Simple Open Cycle with Combustor and Second Turbine



Standard Jet Cycle



Two-Stage Compression, Split-Turbine Jet Cycle



Standard Jet Cycle with Afterburner

GAS TURBINES

The jet units actually produce 30,000 hp or more depending upon speed of the plane.

General Electric's jet units started with Sir Frank Whittle's imported designs during World War II days. This unit had a centrifugal compressor. Today GE builds only axial compressors, except possibly as special units. Their turbines are all of the axial design and even their heavy-duty stationary units have only two or three stages at the most, same as the jet units.

Today, GE is making excellent progress in the manufacture of gas turbines. Fortunately, the losses mentioned in FORTUNE of June, 1954, are now behind them. GE gas turbines are now proven products with years of actual operating experience.

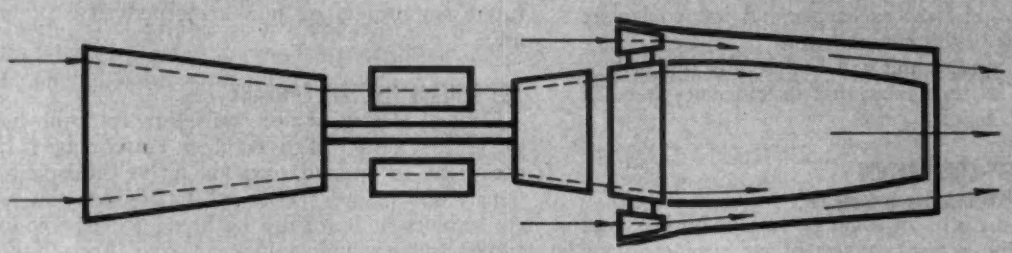
14. GENERAL MOTORS CORPORATION

Allison Division

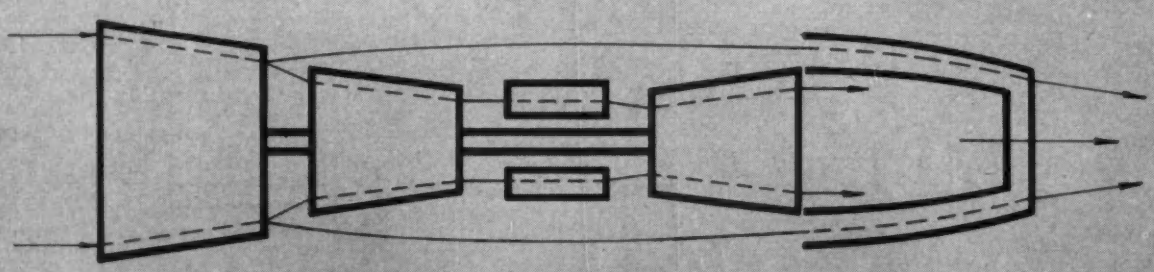
The Allison Division is, at least at this time, the only division of GM (outside of GM Research Laboratories) building gas turbines. They have been in the business for many years and know production methods thoroughly for not only jet units but also for related turboprops and light-weight industrial units.

Range of power for shaft turbines or turboprops is from 200 to over 3000 hp. Range of power for jet units is from 6000 to over 14,000 lb thrust. The jet units are all used in military aircraft. The turboprops are used in both military and commercial planes.

The GMT 305 turbine has already been sold for over a half dozen different military applications to determine its feasibility in each case. This unit has a high efficiency approaching that of the diesel. The results obtained from these applications will be carefully watched as



Standard Jet Cycle with Free Turbine-Driven Ducted Fan



Two-Stage Compression, Two-Combustor Jet Cycle with Ducted Air Flow from First Compresser Stage

considerable production should result. This is the first efficient small turbine to be put into semi-production and GM is to be commended for moving ahead while other builders of regenerative automotive units continue to limit the application of their turbines.

15. NORTH AMERICAN AVIATION INCORPORATED
Rocketdyne Division

Rocketdyne Division is well known for its rocket propulsion units which include gas turbines powering both control units and accessory packages. Range of power for gas turbines in rocket use runs from a few horsepower to many thousands of horsepower, depending on specific application.

It should be stressed that gas turbine designs for rocket application are extremely important. In many cases the turbine is the heart of the control or accessory unit and if it does not function properly, the entire rocket cannot operate. It is true that these turbines are expendable but they are capable of staying together much longer than the life of the rocket in order to insure their reliability.

16. SOLAR AIRCRAFT COMPANY

Solar came into the gas turbine business during the World War II. During this long period of development and production, they have had time to bring out quite a variety of units.

The U. S. Navy purchased most of their early units consisting of the T-520 single-shaft and T-522 split-shaft units both rated around 500 hp. About the same time they brought out the fire-pump unit of 50 hp that has also been used for other purposes as a small generator unit.

Since the early days the T-300 unit has been brought out as an air-starting unit for jets. The latest turbine in service is the T-1000 single-shaft and T-1020 split-shaft unit, both rated well above 1000 hp. Small, very light-weight turbines that range from 70 to 200 hp are also being brought out for helicopter and other services.

Even though Solar is a relatively small company it has done a masterful job in producing fine gas turbines.

17. THIOKOL CHEMICAL CORPORATION
Reaction Motors Division

Reaction Motors Division has a small but excellent turbine department building units necessary in the manufacture of liquid-fueled rockets. This is one of the oldest companies in the business and has to its credit a large variety of sizes and types of liquid-fueled rockets. These have been and are now in service and include the power unit for the present X15 manned rocket.

18. THOMPSON RAMO WOOLDRIDGE, INC.
Tapco Group

TAPCO has been in the gas turbine accessory business for many years. Now they are building not only turbine wheels but complete turbine units. They are also building turbocharger units for diesels.

Space is not available in this article to outline the large variety of gas turbine products built by this company. They range from small rocket-control turbines to ones much larger in physical dimensions. TAPCO has the know-how and is well worth watching.

19. UNITED AIRCRAFT CORPORATION
Pratt & Whitney

It is remarkable how this old-line aircraft engine company has changed over to the gas turbine. Their turboprops range from 500 to over 5000 hp. Their jet units range from 300 to 45,000 lb thrust and include the latest type of turbofan unit now in demand by commercial lines. Including turboprops, jets and jets with afterburners, Pratt & Whitney makes over 16 different units.

Backed with this vast amount of gas turbine experience and extensive production facilities, Pratt & Whitney has announced going into the industrial turbine business. They plan to use jet unit as a gas producer to drive a power turbine built by Cooper-Bessemer, the two companies cooperating on the entire project. We'll hear more about this later when the first unit goes into service.

20. VECTOR CORPORATION

This is a small company that has demonstrated a unique 75 hp unit, one without heat exchanger, the other with a 30%-effective heat exchanger. Actually Vector is responsible for the design while a local manufacturer of other products, McGregor Manufacturing Corporation, has produced the turbines.

21. WESTINGHOUSE ELECTRIC CORPORATION

Westinghouse was one of the first to get into the heavy gas turbine business in this country. They were the first to develop a (small) jet unit without importing the designs.

Their jet units range from 3000 to 6000-lb thrust and are used entirely by the military. The Navy ordered several jet units used as gas producers to drive a Westinghouse marine power turbine. This is a high-power (7500-hp.) light-weight marine unit used primarily for high speed emergency service at sea.

Westinghouse industrial heavy duty turbines range from 3000 to over 20,000 hp. Both turbines and compressors are of the axial multi-stage type designed for maximum efficiency together with long life.

22. WILLIAMS RESEARCH CORPORATION

This is a small company with manufacturing facilities for building complete turbines "the size of a shoe box". These include both units with and without heat exchangers. They are primarily for mobile applications.

IN CONCLUSION one can readily see the vast possibilities for gas turbine units. Even to-day the gas turbine is filling a larger variety of applications than any other single type of prime mover. The gas turbine business is so broad that no one company covers the entire field or even comes close to producing gas turbines for the many present and potential applications.

Blast Furnace Blowing

First such gas turbine installation will soon go into service. Design studies and component tests show economy, excellent performance, operational flexibility—all pointing to an important new market.

FIRST gas turbine to be put to work in a steel mill in this country will begin operation in 1960 at U.S. Steel's South Chicago Works. This 15,000-hp unit, built by Westinghouse, points the way to a promising future for gas turbines in this application.

There are a number of reasons. For one thing, its fuel consumption is 10% better than the steam turbine in this service. The gas turbine requires less space. It can be made to operate without a water system. No boiler is required since furnace gas burns directly in the turbine's combustor. Features such as less space requirement, elimination of the water system are also advantages over the huge old reciprocating engines still in use in the steel industry. These are some of the things U. S. Steel wanted when they decided to make the installation.

More than seven years of research on this project brought out another exciting factor. Not only is a gas turbine system lower in initial cost—but lower in operating and maintenance cost. And now, preliminary engineering tests indicate the overall operating flexibility of the gas turbine blowing unit to be better than anticipated. Through control of the unit itself, it may be capable of running through the entire required pressure and flow ranges without use of external blowing controls.

Big Blow for the Blast Furnace . . . .

The section shows the main air flow and arrangement of equipment. Entering air hits the big compressor. With its 11 axial stages, this component is capable of delivering a pressure ratio up to 4.8 to 1. The compressor delivers a total of 350,000 cu ft of air per min which is divided two ways: 125,000 cu ft per min at 35 psia goes into the blast furnace and 225,000 cu ft enters the heat exchanger or regenerator. After heating to 840°F, which affords a considerable fuel saving, hot air is fed into the combustor where it burns in combination with the blast furnace gas from the fuel compressor.

At 1350°F the hot gases enter and drive the turbine, then, at 950°F, pass through the heat exchanger and exhaust at 540°F. The heat exchanger's effectiveness is about 75%.

The fuel compressor, at left in the section, is also driven by the turbine. Blast furnace gas is delivered to the combustor at 52 psia. The fuel compressor uses about 10% of the amount of power required by the main compressor. Its rating is based on an ambient temperature of 80°F.

8% over . . . .

In the U. S. Steel's South Chicago installation the Westinghouse unit will work in parallel with two steam turbine driven blowers. The new gas turbine will be installed on the existing foundation of the last reciprocating engine at this mill. The gas turbine can blow one furnace on volumetric control or blow two furnaces through split-wind control or blow 2, 3 or 4 furnaces when operating in combination with one steam turbine blower or 5 furnaces with both steam turbines.

On test it has already delivered 8% more than the guaranteed 125,000 cu ft per min to the blast furnace. Projecting what we've already learned from this application, future installations of a non-regenerative gas turbine blower could be run to increase the normal usable output by 20% with an increased fuel flow of 60%.

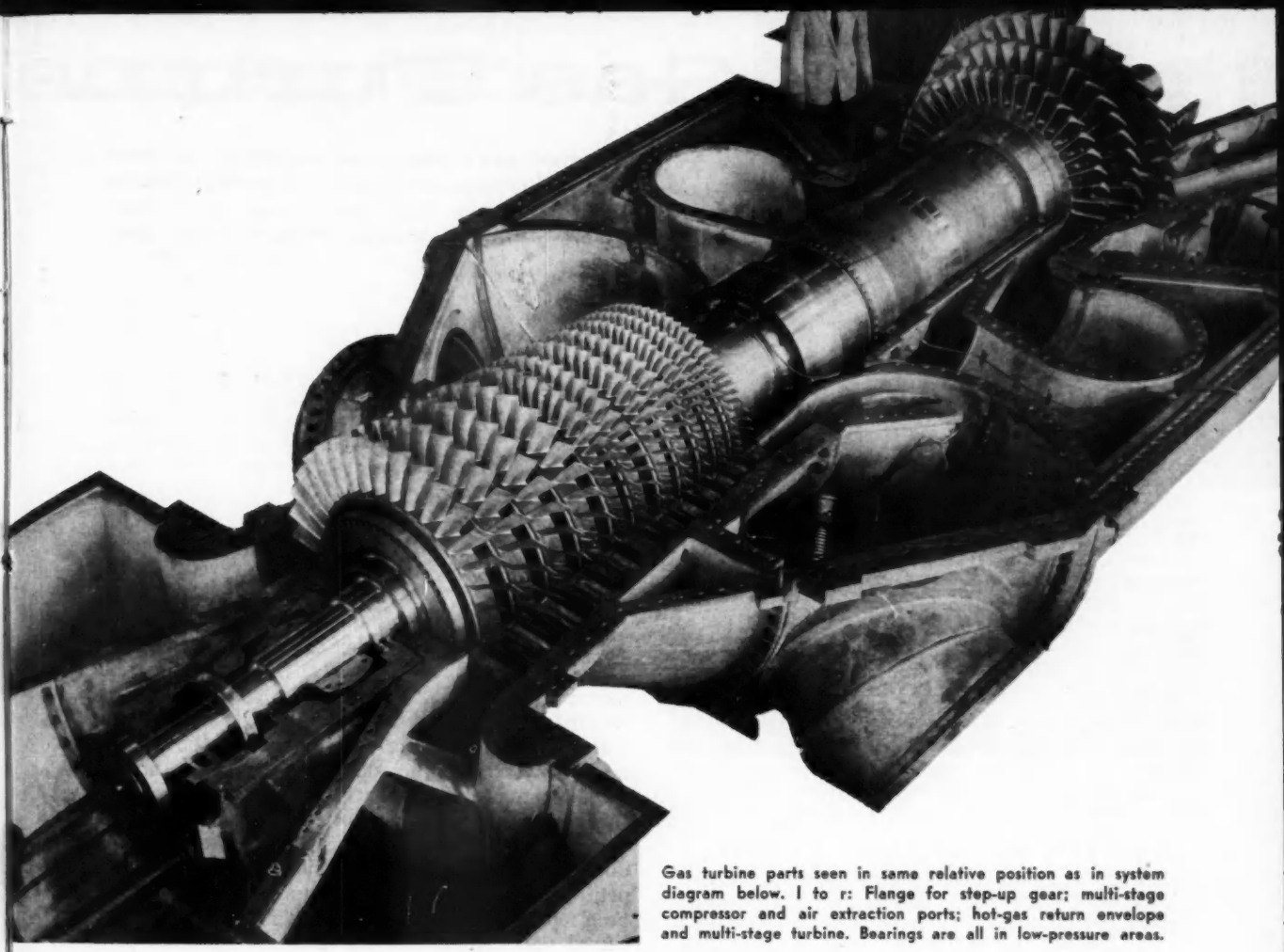
However, the same excellent level of efficiency could be maintained in such installations through use of a waste-heat boiler. This would utilize exhaust heat after the turbine and could produce process steam or feedwater heating for a steam plant. If this heat recovery is added to the overall heat balance, the turbine blower's calculated efficiency looks to be better than the most modern steam turbine blowing plant.

Power for the Future—Now . . . .

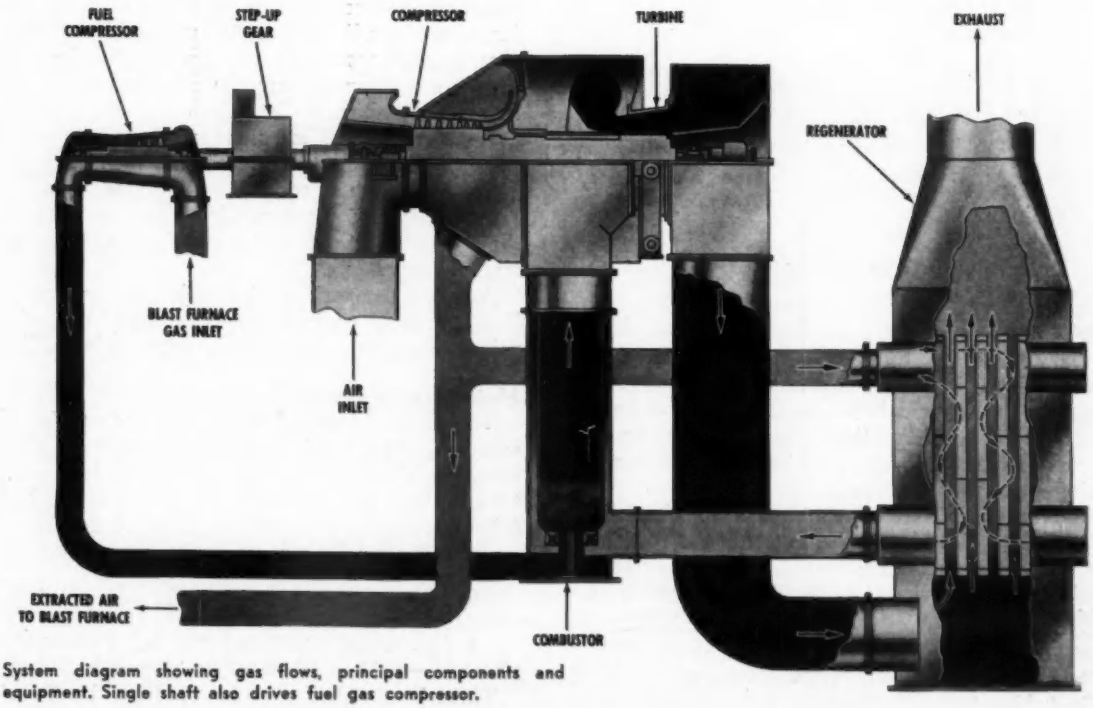
The exciting future of gas turbine applications is broadening rapidly. The table of Westinghouse installations shows units already turning out an aggregate of 680,300 hp. The first Westinghouse industrial unit, installed in 1949, has logged over 60,000 operating hours, probably more than any other gas turbine in the world. Each of the last four applications listed, showing a single unit, is a forerunner of many such installations in the future. The steel mill blast furnace blower unit is one of these, representing power for the future, available now.

TABLE I WESTINGHOUSE GAS TURBINE UNITS

Industry	Units	Horsepower
Oil Field	28	224,000
Electric Power	28	209,000
Natural Gas	14	69,300
Refinery	10	43,400
Marine	7	65,000
Petro-Chemical	4	28,000
Crude Oil	3	24,000
Steel Mill	1	15,000
Chemical	1	1,800
Mobile Power	1	7,000
Mobile Process	1	1,800
Total	98	688,300



Gas turbine parts seen in same relative position as in system diagram below. I to r: Flange for step-up gear; multi-stage compressor and air extraction ports; hot-gas return envelope and multi-stage turbine. Bearings are all in low-pressure areas.

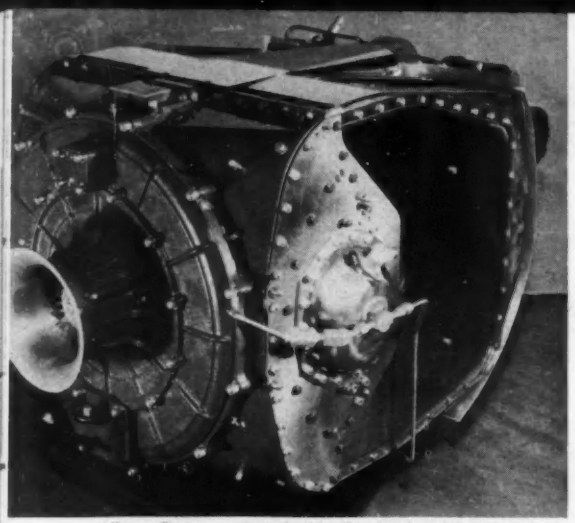


System diagram showing gas flows, principal components and equipment. Single shaft also drives fuel gas compressor.

Gas Turbine

Now, gas turbines can be selected for many applications with predictable results projected from actual field service experience. Here is a record of accomplishments* to date.

*From the paper entitled "Gas Turbines — Demonstrated Ability", John W. Sawyer, Journal of the American Society of Naval Engineers, Inc., August 1959, pp 529-534



Allison Division, GM, builds the 225-hp GT-305 with the unusually low specific fuel consumption of 0.55 lb per hp hr. They are now being built for several specific applications. Small regenerative gas turbines are finding new applications through performance with good economy.

DESIGNERS today are selecting gas turbines to do jobs that cannot be done as well by other prime movers. Installation of the gas turbine to gain experience on which to base further design improvements is now no longer necessary in certain cases. Reliable and proven gas turbines are being chosen for use in many fields including:

a. Aviation
   1. Turboprop
   2. Turbojet
   3. Auxiliary power supply
   4. Propulsion engine starting
b. Industrial
   1. Propulsion, locomotive
   2. Power generation, central station
   3. Air supply, steel blast furnaces
   4. Chemical process
   5. Pump drives
   6. Oil field generation, electrical
   7. Gas line pumping
c. Marine
   1. Propulsion
   2. Generation, electrical
   3. Pump drive
   4. Air supply
   5. Starting for larger gas turbines
   6. Fog generation

Initial Cost

Initial costs of gas turbines have steadily decreased. When produced in quantities compared to other prime movers the cost should be no greater as, for example, compared to the reciprocating internal combustion engine or less than the steam turbine-boiler plant combination.

Prime movers for a 6200-kw mobile power plant were studied. The following relative cost for the complete plant was determined (1):

Prime Mover	Cost of Complete Plant — Percent
Diesel	150
Steam turbine-boiler	130
Gas turbine	100

From these cost comparisons the gas turbine plant was selected in preference to either diesel or steam turbine. The diesel considered here was of the heavy-duty type having the same long life of the gas turbine that was selected. Lighter-weight diesels could be obtained to match or even be less than the first cost of the gas turbine. However, whether diesel, steam turbine or gas turbine portable power plants are selected, factors other than first cost must be considered.

In the marine field numerous studies have been conducted which show the gas turbine to be highly competitive in initial cost with other prime movers. It has been reported that gas turbine machinery cost will not exceed 1.16 that of heavy-oil machinery, or 1.09 that for the steam turbine. It is believed that costs will be materially reduced by new and improved manufacturing methods and materials. A second study (2) indicates that installed cost of a marine gas turbine plant will be less than a steam turbine plant in sizes generally used in merchant ships.

Installed cost of an unattended, remote-controlled pumping unit, located in a desert, including 5000-hp gas turbines with all controls and portable shop installations, is actually very much less than that of a typical diesel station with its vast array of supporting facilities and personnel (3).

A recent comparison of available gas turbines, gasoline and diesel engines shows the initial cost of these prime movers on a dollar per horsepower basis, Table 1.

Maintenance Costs

The Shell Company's experience with reciprocating engines and gas turbines, all for generation of electrical power in Venezuelan oil fields, has provided some interesting information. A central power station had the following engines installed for power generation:

a. 6 dual-fuel internal combustion reciprocating engines, each 500 kw.
b. 2 internal combustion reciprocating engines, each 950 kw.
c. 1 gas turbine, (Metropolitan Vickers) 1750 kw
d. 1 gas turbine, (Gasturbine Maat, N.V.) 2000 kw.
e. 2 gas turbines, (General Electric) 5000 kw.

There is a total of 4900 kw produced by the piston

engines, or 26% of the total, as compared to 13,750 kw produced by gas turbines.

Tabulation of the comparative cost on a kw-hr basis is as follows:

Engine	Cost-Pence/kw-hr. Operation	Maintenance	Combined
Gas Turbine	0.196	0.142	0.338
Piston Engine	0.381	0.262	0.643

This clearly shows it is more economical to have a few large gas turbines compared to a multiplicity of smaller diesels.

Union Pacific Railroad experience with gas turbines, diesels and steam engines is illustrated in Table 2. These turbine locomotives are on special runs and are keeping within the operating and maintenance costs of the diesels. The 8500-hp locomotives have now been delivered and we will hear more about them later.

Overhaul costs, on Dart turboprop engines operated by Capital Airlines are $3.50 per engine flight hour (4). These engines had accumulated some 300,220 flight hours prior to December 1957. At that time, engine hours per failure on the Dart 506 gas turbine were 21,444. Experience with the Dart 510 indicated some 115,000 engine hours per failure. The following relates to overhaul cost, material and labor, on these engines in 1957:

a. Hours between overhauls (CAA approved) 1500
b. Average bare engine overhaul (labor) $1150.00
c. Average bare engine overhaul (man-hours) 490
d. Average bare engine overhaul (material) $3850.00
e. Overhaul cost per flight hour $3.51

These figures have, of course, been improved in the past two years.

Operating experience, over a period of some 34,000 hours with a 5400-kw gas turbine at Luxembourg showed a maintenance cost of 0.0695 US Mills/kw-hr (5). Steel mills throughout the world are now considering use of gas turbines with future blast furnace expansion.

The General Electric 6600-hp gas turbine in the JOHN SERGEANT during its operation to date, representing some two years during which she sailed over 94,000 nautical miles with 6567 hours operation, has shown superiority over a marine diesel prime mover due to freedom from maintenance (6).

Availability

Intensive development and rapidly expanding use of the heavy-duty gas turbine accounts for its enviable record of availability.

A 5400-kw gas turbine plant, normally operating on blast furnace gas but with provisions for use of liquid fuel, had a total running time, as of June 1956, of 33,362 hours. During this time, availability factor was greater than 86% (5).

With one power-generating gas turbine set with over 27,000 hours operation, availability has been 89.4%.

Ford's gas turbine installed in a passenger car. There is a long list of companies that are experimenting with gas turbines in cars. Most serious contenders at present are the Big Three—Ford, GM and Chrysler; England's Austin and Rover; Italy's Fiat.

An analysis of a number of base-load gas turbines with use factors greater than 96%, revealed that average availability was 98.17%. These units had operated a total of 68,890 hours (8).

The light-weight high-speed gas turbine is now equal to the reliability of the high-speed engine turbocharger.

Overhaul Interval

Hours of operation between overhauls of gas turbines vary over an exceptionally wide range. These overhaul intervals depend on many factors including: type of service, utilization, reliability, availability, fuel, materials and design. The term "overhaul interval" is preferred to the one "overhaul life" because the latter suggests that at the end of a given period the engine is for all practical use, to be torn down and have all parts replaced. This is not true by any means as an overhaul on a 500-hp marine gas turbine indicates an overhaul cost of only 5 to 10% of initial engine cost.

It is not unusual for large indus'rial-type gas turbines to operate many thousands of hours without inspection, let alone overhaul. For examples the following operating experiences are cited:

a. 5000-kw Brown-Boveri gas turbine used by Arabian Oil Company operated over 15,000 hours prior to inspection (5).

b. 6600-hp General Electric gas turbine propulsion plant on GTV JOHN SERGEANT operated 6567 hours and 94,000 nautical miles without any maintenance (6).

Small gas turbines in the 50 to 1000-hp range are on relatively long overhaul intervals. Turbines in marine service have shown remarkably long operating periods.

Some engines in this class have experience as follows:

a. 500-hp Solar propulsion turbine, operated some 800 hours at sea, driving a 40-ft boat over 16,000 miles at speeds in excess of 25 knots. Most operation was at 97% of rated speed.

b. 160-hp Boeing generator-drive engines have a required 500-hr overhaul. In order to determine a longer overhaul period, one engine has operated on laboratory test for 2500 hours without overhaul. Some minor parts were replaced during this test. Some 184 Boeing engines are in use by the U.S. Navy.

Aircraft experience with propulsion gas turbines has been very good. Engine overhaul interval is steadily increasing. Commercial airline service has shown that maintenance cost for reciprocating engines per engine flight hour is more than 200% of maintenance cost of gas turbines.

Data presented on the Dart gas turbine, powering Capital Airline Viscounts, shows time between overhauls of 1500 hours, prior to December, 1957 (4). It is understood that other gas turbines on commercial lines also have long overhaul intervals. Time between overhauls on gas turbines is *steadily increasing* even though they have already exceeded the piston engine.

The Bristol Proteus 705 aircraft engine had an overhaul interval of 500 hours when it was first placed in passenger service. In less than two years this overhaul interval had been increased to 2000 hours (10).

Reliability

The gas turbine has well demonstrated its reliability in aviation, industrial, transportation, and marine fields. Base load machines have reliability such that they have been accepted by public utilities for power generation.

A 5000-kw gas turbine-driven generator supplying power at an oil field location (7) has been installed for about 24,000 hours. During this period forced outage was 10 hours. Reliability of this unit has exceeded 99.9%. At the same location a second gas turbine has been installed for some 21,600 hours. This unit has experienced a forced outage of 20 hours and has a reliability of at least 99.9%.

In a gas turbine generator set supplying electric power for a utility company the unit has been down for 34 hours due to forced outages. Installed time for this engine was 31,542 hours. This gives a reliability factor of 99.85%.

Operating Personnel

Reduction of operating personnel costs is an attractive means of lowering overall operating costs. In a number of applications the gas turbine has demonstrated its advantage in this respect over reciprocating combustion engines and steam turbines.

Industrial use of gas turbines in rail service amply illustrates the fact that generally lower personnel costs are obtained in operating the gas turbine plant. The Union Pacific found its cost in cents/1000 gross ton mile for enginemen was 14.22 with gas turbine and 18.79 for diesel-driven locomotives. This shows approximately 25% reduction in personnel costs for gas turbine-powered locomotive operation.

In the marine field, reduction in size of engine operating crews by use of the gas turbine is equally attractive. The U.S. Maritime Administration converted four Liberty ships from their original propulsion plants which were reciprocating steam engines. These ships with engine room personnel are shown in the following tabulation:

Ship	Propulsion Plant	Engineroom Personnel	Relative Crew Size
John Sergeant	Gas Turbine	12	1.00
Thomas Nelson	Diesel	14	1.16
Benjamin Chew	Steam Turbine	16	1.33
William Patterson	Free Piston/Gas Turbine	12	1.00

These ships were operated by commercial companies. Engine room crew for the diesel ship is 16% greater than for the gas turbine, while the steam turbine engine room crew is 33% greater than that of the gas turbine ship. This is almost significant factor . . . "when one considers that reduction of one man per watch can result in a saving in operating cost comparable to an improvement of about 10% (in overall plant efficiency) on a cargo vessel with a propulsion plant rated at 20,000 hp (based on 5000 operating hours per year underway and fuel costing $2.70 per barrel)" (2).

Dependability, simplicity and requirement for a relatively small number of supporting auxiliaries and services are the main reasons for the small number of operating personnel needed for a gas turbine installation. Gas turbines are ideally suited for operation by remote control. This is true of industrial as well as marine-type installations. An outstanding illustration of remote control operation is the new pumping plant of the Trans-Arabian Pipe Line Company (3).

This station consists of six pumping units driven by 5000-hp gas tubines. These turbines are fueled with crude oil taken directly from the pipeline. They are required to operate throughout an ambient temperature range of 30°-120°F. The radio control positions are 50 to 100 miles away from the turbines.

Conclusion

With these impressive experiences compiled by gas turbines during recent years it is expected that their rate of application will be greatly accelerated in the immediate future.

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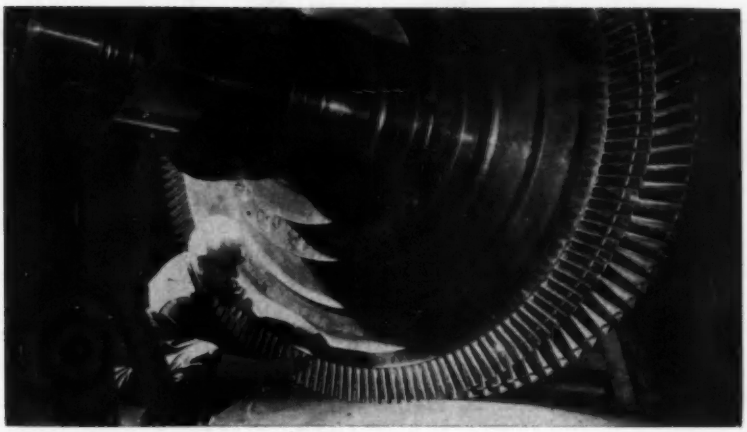

Five-ton, 84-in. gas turbine rotor is checked by worksman in GE's Gas Turbine Department. Today, over 200 gas turbines have been shipped from the Schenectady plant and they have accumulated close to 4-million hours of service.

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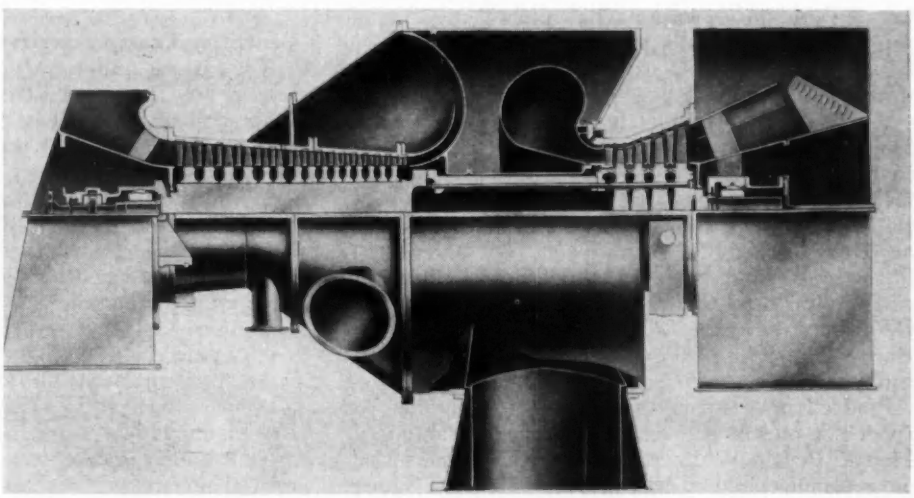
Table 1 GAS TURBINES

Manufacturer	Name	Hp	Lb/Hp	Cost/Hp	Fuel Rate Per Hp-Hr
Allison	GMT-305	225	2.65	—	0.55
AiResearch		30-1000	0.40	$18,000-$25,000*	0.65
Boeing	502-10C	240	1.36	$62.5	0.7-1.0
General Electric	T-58	800	0.34	—	0.69
Clark Bros.	Mark TA	1220	10.00	$80-$110	0.91
Continental	TC 106	160 (Air hp.)	—	—	—
Lycoming	T-53	700	0.69	$30	0.75
Solar	Jupiter	500	1.10	$100	0.95
Solar	Saturn	1000	0.75	$50	0.65
				*Total Price	
		THEIR CHIEF RIVALS			
Chrysler Marine V-8 (Gasoline)	Imperial special	225	4.70	$11.10	0.61
Aircraft Type (Gasoline)	Allison V-12	1250	0.995		0.52
Diesels		20-500	6-10	$16-$30	0.4-0.55

Table 2 Costs in cents/1000 gross ton mile

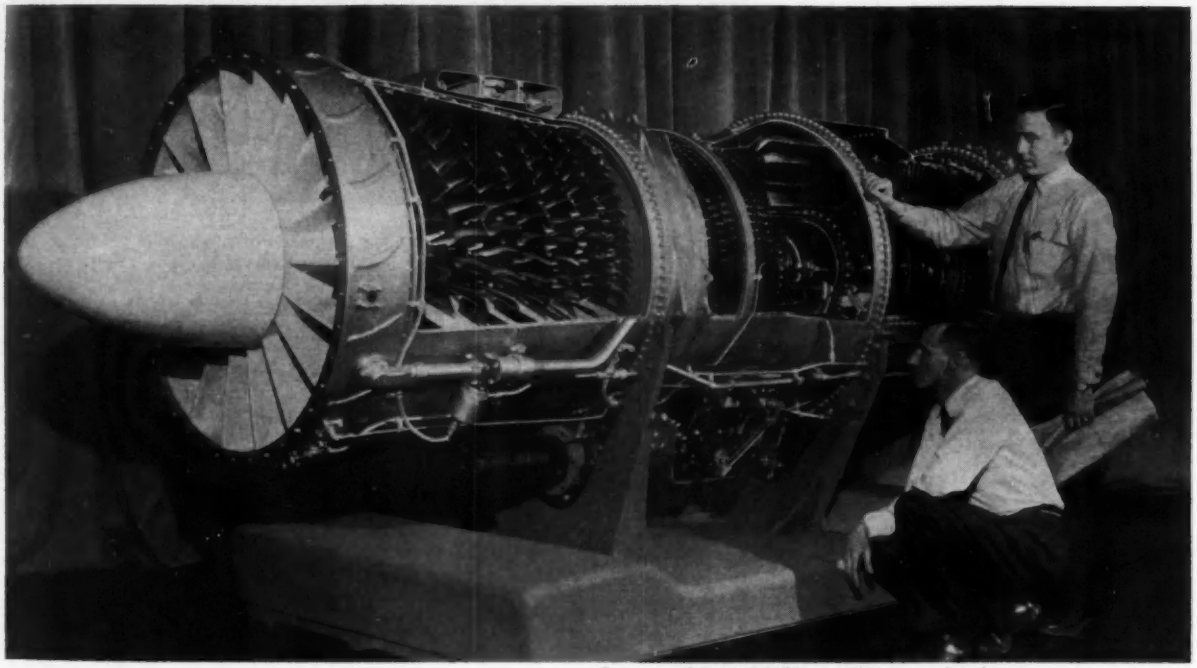
	Steam	Diesel	Gas Turbine
Repairs	27.44	16.56	14.45
Engine house	14.89	3.66	2.24
Fuel	54.99	20.12	22.23
Lubricants	1.47	1.40	.47
Other supplies	5.65	.16	.04
Enginemen	18.28	18.79	14.22
Trainmen	22.42	23.34	15.54
Total	145.14	84.03	69.19

Table, left, from Business Week, Jan. 17, 1959, compares gas turbines and rivals. Table, above, is Union Pacific cost comparison of steam, diesel and gas turbine locomotives given back in Sept., 1954.



Typical gas turbine design for heavy-duty industrial use. This Westinghouse W-201 unit is rated 18,500 kw for base-load use and 22,000 kw for peaking. This unit has one combustor but up to 12 may be used, depending on application.

gas turbines



Cutaway of Pratt & Whitney JT4A 2-spool turbojet used in most long-range airliners.

for AIRLINERS

by Paul H. Wilkinson

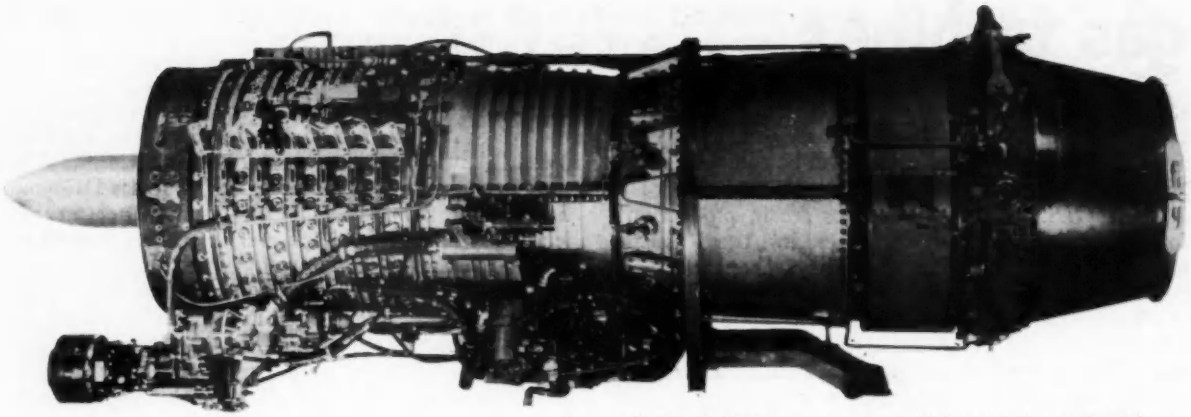
TEN years ago, there were no gas turbine airliners in regular service in any part of the world. Five years ago, relatively few airliners equipped with gas turbine power plants were in use. Today, there appears to be no limit to the ever-expanding services offered all over the world by fast subsonic airliners powered with gas turbines. For tomorrow, aircraft and power plant manufacturers are already beginning to prepare preliminary designs for airliners with supersonic speeds.

The gas turbines that have made these phenomenal strides in commercial air transport possible are the products of eight manufacturers, if the government owned and operated engine factories in the U.S.S.R. are considered as two units—one for turbojets and one for turboprops. In the United States, Allison Division of General Motors, General Electric and Pratt & Whitney Division of United Aircraft build the big engines. In England, manufacturers of gas turbines for these civil aircraft are Bristol Siddeley, Napier, and Rolls-Royce. Designing, developing and producing these costly engines is big business which only large organizations can handle.

Production of aircraft gas turbines for airliners is divided at present between turbojets built by General Electric, Pratt & Whitney, and Rolls-Royce and turboprops manufactured by Allison, Bristol Siddeley, Napier and Rolls-Royce. In the U.S.S.R., both types of powerplants are in production and in airline service. With the exception of the Bristol Siddeley and Napier engines, and two models of Rolls-Royce origin, all of these civil gas turbines were developed from military engines for which relatively unlimited government funds were available.

Centrifugal compressor types lead the parade . . .

The first gas turbine engine to go into regular airline service was a turbojet. This was the De Havilland Ghost 50 that had a 2-stage centrifugal-type compressor and a 1-stage turbine. It was rated 5000 lbt (pounds thrust). Four such engines powered the 36-passenger De Havilland Comet 1 airliner that was placed in service to the Near East by British Overseas Airlines in May, 1952. The 44-passenger Comet 1A which followed was equipped with Ghost 50 Mk.2 engines of the same rating, equipped with water injection to restore take-off power in hot climates. These 490-mph jet airliners pioneered the way for today's high-speed transports. Unfortunately, the Comets were permanently grounded after a year's successful operation because of structural failure of the airframe. The engines were not at fault but the Ghosts were never used again in commercial aircraft.



General Electric CJ-805-3 turbojet powers high-speed Convair jet airliners.

The Rolls-Royce Dart was the next gas turbine to make its appearance in an airliner. It was a turboprop with a 2-stage centrifugal-type compressor and a 1-stage turbine. Four Dart 3's provided power for the 310-mph, Vickers Viscount 700-series, 40-passenger airliner when it was put in service by British European Airways in April, 1953. The Dart 3 was rated 1540 ehp (equivalent hp), or 1400 shp plus 365 (residual) lbt. The Dart 6 is a later model with a rating of 1740 ehp that is used in the 320-mph, 700D-series, 44-to-48 passenger Viscounts supplied to Capital Airlines, and in 800-series, 53-to-65 passenger Viscounts. This engine is also used in 2-engine, 24-to-40 passenger Fokker F. 27 Friendship airliners produced by Fokker in the Netherlands and Fairchild in the United States.

Latest model of this turboprop, known as the Dart 7, has an improved 2-stage compressor with increased pressure ratio and air mass flow, and a 3-stage turbine. The Dart 7/1 of this series, rated 1990 ehp, is used in the 365-mph, Viscount 810, 52-to-75 passenger airliner and in the 300-mph, 30-to-44 passenger, F.27A Friendship. The Dart 11 is an advanced model with a larger compressor, higher pressure ratio and air mass flow, and air-cooled turbine blades, that is rated 2,350 ehp. It is used in the Vickers Viscount 840 that cruises at 400 mph.

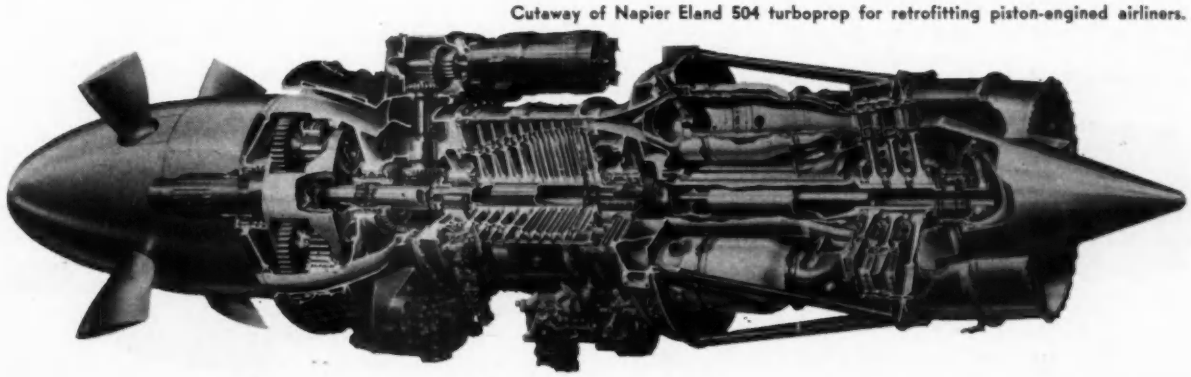
Axial flow types for higher power . . .

When more powerful engines were required for larger airliners, it became necessary to turn to axial-type gas turbines with their higher air pressure ratios and air mass flow. By now, the Bristol Proteus turboprop was available to meet the requirement. It has a 12-stage axial compressor with a final centrifugal stage to reverse the forward air flow, and a 4-stage turbine. The Proteus 705 that powered the 4-engine, 79-to-108 passenger, Bristol Britannia 102 airliner, first placed in service by British Overseas Airways in December, 1955, was rated 3900 ehp. The Proteus 765 rated 4445 shp now provides a cruising speed of 400 mph for the latest model of the 82-to-148 passenger Britannia used by Canadian Pacific Airlines.

The only American turboprop that is in production and in regular service on the airlines is the Allison 501. This engine is a small-diameter power plant, with an extension drive to the propeller reduction gearbox. It has a 14-stage axial compressor and a 4-stage turbine. The 501-D13 now in production is rated 3750 ehp and powers the 400-mph, 4-engine, 66-to-99 passenger Lockheed Electra airliner, first placed in service by Eastern Airlines in January, 1959. Another model—the 501-D15—is rated 4050 ehp. These engines were developed concurrently with military models that are used extensively in transport planes.

Another turboprop that is entering production is the Rolls-Royce Tyne. It will be used in medium-range airliners such as the 425-mph, 4-engine, 76-to-139 passenger Vickers Vanguard. The Tyne is a 2-spool axial-type engine, with a 6-stage low-pressure compressor driven by the 2nd, 3rd and 4th-stage turbine wheels, and a 9-stage high-pressure compressor driven by the 1st-stage turbine. Concentric drive shafts are used. The Tyne 1,

Cutaway of Napier Eland 504 turboprop for retrofitting piston-engined airliners.



gas turbines for AIRLINERS

rated 4985 ehp, is being fitted to the first Vanguards for British European Airways, but later aircraft for this airline and Trans-Canada Airlines will be equipped with the Tyne 11 rated 5545 ehp.

In the U.S.S.R., two turboprops are in production for the latest airliners used by Aeroflot, the Russian national airline. These engines—the Ivchenka IA-20, rated 4000 shp, powers the 400-mph, 4-engine, Iluyshin IL-18A, 100-passenger airliner and the 4-engine Antonov AN-10A airliner of about the same size. The Kuznetsov NK-12M engine which embodies a 14-stage compressor and a 5-stage turbine, has a rating of 13,000 ehp or 12,000 shp. It is the largest and most powerful turboprop in the world. It is equipped with 4-blade counter-rotating propellers. This engine powers the largest airliner in the world—the 400-mph, 4-engine, 120-to-220 passenger, long-range Tupelov TU-114D.

Retrofitting—a good market . . .

An important new use for turboprops is now being developed that may result in modernization of hundreds of piston-engined airliners now being rendered obsolescent by the advent of new airliners powered with gas turbines. This new project consists of retrofitting these older airliners—Convair 340's and 440's, Douglas DC-6's and DC-7's, and Lockheed Constellations—with turboprops to increase their speed, payload and range. It will also enable operators to use the magic word "jet" when referring to these rejuvenated aircraft—a word which means so much to the traveling public today.

Retrofitting of five Convair 440, 44-passenger airliners for Alleghany Airlines has already begun, with an option on modernizing ten more of these aircraft. Engines being installed in them are Napier Eland 504 axial-type turboprops, rated 3500 ehp. This well-tried power plant of simple straight-forward design, embodying a 10-stage compressor and a 3-stage turbine, is also in production as original equipment for similar 320-mph aircraft now being built by Canadair in Canada.

American commercial developments . . .

The first high-power, axial-type turbojet to be placed in production for airliners in the United States was the Pratt & Whitney JT3C-6. It is the commercial version of the highly successful J57 engine that is widely used in military aircraft. The JT3C-6 powered the 600-mph, 4-engine, 121-to-179 passenger, Boeing 707-120-Stratoliner when it was first placed in scheduled service across the North Atlantic in October, 1958, by Pan American World Airways. This engine is also used in the 600-mph, 4-engine, 116-to-176 passenger, Douglas DC-8 airliner. It is rated 13,000 lbt at take-off, with water injection. It has a 2-spool compressor with a 9-stage low-pressure section and a 7-stage high-pressure section, and a 3-stage turbine. In a later model known as the JT3C-7, a saving of more than 700 lbs in weight has been accomplished by use of titanium for the compressor and other parts.

The larger Pratt-Whitney JT4A-3, which corresponds to the military J75 turbojet, is being fitted in the long-range, 4-engine, Boeing 707-220 and 770-320 Stratoliners and Douglas DC-8 Continental and Intercontinental airliners. This engine, also of the 2-spool type with similar compressor and turbine arrangement to the JT3C-6 but of larger diameter, is rated 15,800 lbt at take-off, without water injection. Other models such as the JT4A-11 and JT4A-12 will soon be available with ratings up to 17,500 lbt, with water injection.

Another American turbojet that is now in production for airliners is the General Electric CJ-805-3. It is a commercial development of the military J79. The CJ-805-3 has a 17-stage axial compressor and a 3-stage turbine. Starting and ground operation are facilitated by using variable-incidence stator blades for the first six compressor stages. They regulate air pressure and are controlled by actuators operated by fuel-flow pressure. The engine is rated 11,200 lbt and will power the 615-mph 4-engine 88-to-110 passenger Convair 880 Intercontinental airliner, soon to be placed in service by Trans-World Airlines and Delta Airlines.

Ducted fan models of both the Pratt & Whitney JT3 and General Electric CJ-805 turbojets have been developed to provide additional air thrust externally and give more power at take-off, thereby reducing length of runway required. Specific fuel consumption is also reduced, thereby increasing range. The Pratt & Whitney JT3D-1, with its ducted fan at the front of the engine, is rated 17,000 lbt. The General Electric CJ-805-23, with its "aft fan" at the rear, gives 16,000 lbt at take-off.

Development abroad . . .

The first axial-type turbojet for airlines to go into production in Great Britain was the Rolls-Royce Avon

(Concluded on page 33)

Allison 501-D13 turboprop with extension gearbox powers Lockheed Electra airliners.

ASME Gas Turbine Power Division Conference Program

Here is a preliminary program issued by the Gas Turbine Power Division for the Fifth Annual Conference and Exhibit to be held March 6-9, 1960 at the Rice Hotel in Houston Texas. Don't miss this most important engineering conference of the year . . .

MONDAY, March 7th

8:30 A.M.—Exhibits Open.

9:00 to 11:30 A.M.

Gas Turbine Division Session No. 1

"Operation and Maintenance of Remotely Controlled Gas Turbine Units"
by Ross C. Hill, Trans-Arabian Pipeline Co.
Beirut, Lebanon

"Comparison of Operating Characteristics of a Dual Shaft Gas Turbine With a Single Shaft Gas Turbine for Gas Line Pumping"
by Mark J. McDonough, Westinghouse Electric Corp., Philadelphia, Pa.

"Operating Experience on Nimonic 80A First Stage Turbine Buckets on Natural Gas"
by A. W. Herbenar and G. R. Heckman, General Electric Co., Schenectady, N. Y.

Joint Session No. 1 (with Hydraulics Division)

Symposium on Compressor Stall, Surge and System Response—I.

12:30 to 2:30 P.M.—WELCOMING LUNCHEON

2:30 to 5:00 P.M.—

Gas Turbine Division Session No. 2

"Application of Gas Turbines in Industry"
by C. R. Apitz, Clark Brothers Co.

"Report on 9,000 Hours Operation of Marine Propulsion Gas Turbine in the JOHN SERGEANT"
by C. C. Tangerini, U. S. Maritime Administration, Washington, D. C. and W. H. Van Cott, United States Lines, and H. D. McLean, General Electric Co., Schenectady, N. Y.

"1,100 HP Gas Turbine for Marine Application"
by Paul A. Pitt, Solar Aircraft Co., San Diego, Calif., and Cdr. R. G. Mills, Bureau of Ships, Washington, D. C.

Joint Session No. 2 (with Hydraulics Division)

Symposium on Compressor Stall, Surge and System Response—II.

6:30 P.M.—Exhibits Close.

7:30 to 9:30 P.M.

Joint Session No. 3 (with Hydraulics Division)

Symposium on Compressor Stall, Surge and System Response—III.

TUESDAY, March 8th

8:30 A.M.—Exhibits Open.

9:00 to 11:30 A.M.

Gas Turbine Division Session No. 3

"Gas-Steam Power Generation"

by P. T. Martinuzzi, Prof. of Mech. Engrg., Stevens Institute of Technology

"Economics of the Combined Steam Gas Turbine Exhaust Heat Cycle for Medium Size Electric Utilities"

by Warren M. Sybert, Kaiser Engineers, Oakland, Calif.

"Heat Recovery from Gas Turbine Exhaust"

by G. L. Morris, Brown & Root, Inc., Houston, Texas.

2:30 to 5:00 P.M.

Gas Turbine Division Session No. 4

"Operating Experience with a 15MW Blast Furnace Fired Gas Turbine in a German Steel Mill"

by F. K. Koenig, Director
Huettenwerk Rheinhausen, Germany

"Three Years' Operating Experience with 7,500 Kw Gas Turbine Plants in Belgian Steelworks"

by E.Aguet and J. de Salis, Sulzer Brothers, Ltd., Switzerland.

WEDNESDAY, March 9th

8:30 A.M.—Exhibits Open.

9:00 to 11:30 A.M.

Gas Turbine Division Session No. 5

"Experience with Gas Turbines in French Power Stations"

by Dr. P. Chambadal, Electricite de France, Paris, France.

"Gas Turbine Operating Considerations and Experiences at El Convento"

by O. H. Pfersdorff, Electricidad de Caracas, Caracas, Venezuela.

"A Rapid Starting Automatic Gas Turbine Generating Plant for Peak Load Duty"

by B. G. Markham, Bristol Siddeley Engines, Ltd., Bristol, England.

Joint Session 4. (with Hydraulics Division)

Compressor I.

"Compressor Performances Evaluation with Complex Gas Mixtures"

by F. W. Peterson, M. W. Kellogg Company

"Correlation of Stage Performance with Different Test Fluids"

by F. Wiesner, Carrier Corporation.

"Correlation of Turbo Compressor Performance with Various Gases"

by C. A. Macaluso, Worthington Corporation.

12:30 to 2:30 P.M.—GAS TURBINE POWER DIVISION LUNCHEON

Speaker—Walker Cisler, Pres. ASME & Pres. of Detroit Edison.

2:30 P.M.—Exhibits Close.

2:30 to 5 P.M.

Gas Turbine Division Session No. 6

"The Behavior of Gas Turbine Combustion Chambers While Burning Different Fuels"

by C. Kind, Brown, Boveri & Co., Ltd.,
Baden, Switzerland.

"Smoke Reduction in Residual Fuel Burning Gas Turbine Combustion System"

by J. B. Gatzemeyer, R. B. Schiefer and N. R. Dibelius, General Electric Co., Schenectady, N. Y.

7:30 to 9:30 P.M.—Committee Meetings

MGCR--marine propulsion

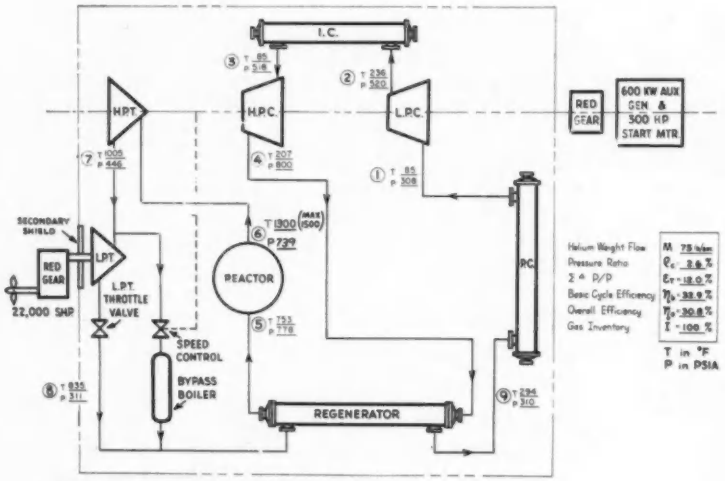


Fig. 1 MGCR Design Flow Sheet for prototype with constant-speed turbo-compressor.

by Harry L. Browne

Combining the closed-cycle gas turbine with a nuclear reactor provides a marine propulsion power plant with very attractive features, promises widespread use.

Abstract of a paper "The Maritime Gas-Cooled Reactor Propulsion Plant of the Future" presented at the Annual Meeting of Atomic Industrial Forum in Washington, D. C., November 2, 1959 by Harry L. Browne, Sidney A. Bernsen and the MGCR Project Stalls of General Dynamics Corporation's General Atomic and Electric Boat Divisions.

OUR GOVERNMENT, through its agencies, the Atomic Energy Commission and Maritime Administration, has recognized the importance of seeking economic improvements through nuclear energy application. It has instituted an orderly program of development to achieve this end. This program began, logically, with a system already the object of several years of effort and millions of dollars in cost and which had demonstrated its success in the Navy submarine NAUTILUS and its progeny.

Other, more-advanced systems that are under current investigation may bring the art and economics much closer to the goal of more efficient power plants. The system which we believe is capable of doing this is one that couples the gas-cooled nuclear reactor to the closed-cycle gas-turbine power plant, the Maritime Gas-Cooled Reactor, or MGCR, Program.

Fundamental advantage of the MGCR over other nuclear systems lies in its ability to (1) attain higher temperatures from a nuclear heat source and (2) utilize these higher temperatures more efficiently. The higher temperature is attained through the use of an inert coolant, helium, which in turn permits use of refractory metals, such as niobium and molybdenum, and of ceramics, such as graphite, as structural materials on the high-temperature portions of the system.

Its high temperature is used more effectively, in terms of efficiency, because at temperatures of 1300° F and above the thermodynamic-cycle characteristics favor the gas-turbine cycle over any steam cycle practical for maritime application.

Primary responsibility for the MGCR program has been placed by its sponsors, the Atomic Energy Commission and the Maritime Administration, with General Dynamics Corporation.

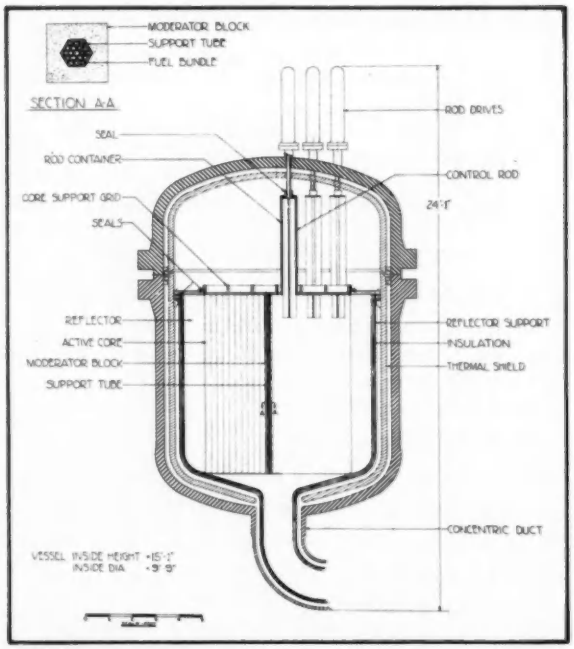


Fig. 2 Details of reactor used in MGCR power plant.

The MGCR System

Working fluid (gas) heated in the reactor (Fig. 2) is expanded through the high-pressure turbine, which drives the compressors, and a low-pressure turbine that provides the output power. Leaving the low-pressure turbine, the working gas enters the hot side of the regenerator where it is reduced in temperature. From the

plant of the future

regenerator, gas enters the water-cooled precooler where part of the cycle waste heat is rejected.

The regeneration process enables waste heat to be rejected at a lower average temperature, thereby increasing efficiency of the process. Working gas leaves the precooler and enters the low-pressure compressor where its pressure is raised to an intermediate level.

After heat of compression is rejected to the intercooler, working gas enters the high-pressure compressor, where it is raised to peak cycle pressure. Upon leaving the high-pressure compressor, working gas passes through the cold side of the regenerator where it absorbs the heat given up by the gas on the hot side. It then returns to the reactor, thus completing the cycle.

The reactor core is 6.4 ft in diameter and 6.4 ft high and is surrounded by a reflector. The core is made up of moderator elements that contain the fuel elements. Moderator material is scheduled to be beryllium oxide due to a very substantial reduction in its cost. The reflector will be either graphite or beryllium oxide.

The U^{235} loading is currently specified as 208 kg. This loading results in an enrichment of 5% and an estimated core lifetime (assuming uniform burnup) of over five years at full power.

MGCR turbomachinery consists of four separate components: low-pressure compressor, high-pressure compressor, high-pressure turbine and low-pressure turbine (Fig. 3). The high-pressure turbine supplies power to drive the two compressors and is coupled directly to them. The low-pressure turbine provides propulsion power and is mounted on a separate shaft which is in line with, but not coupled to, the high-pressure turbine-compressor shaft.

All turbomachinery stages are of the axial-flow type. Design details have been chosen from a parametric study of the effect of several basic variables, including type and amount of pre-rotation, flow coefficient, and hub-tip ratio. Calculated performance will be confirmed by model tests.

Present tentative design of the turbomachinery calls for the compressor-turbine set to turn 12,200 rpm. There are 38 compressor stages, of which 17 are in the low-pressure compressor and 21 are in the high-pressure compressor. Each turbine has eight stages. Design speed of the power turbine is 8000 rpm.

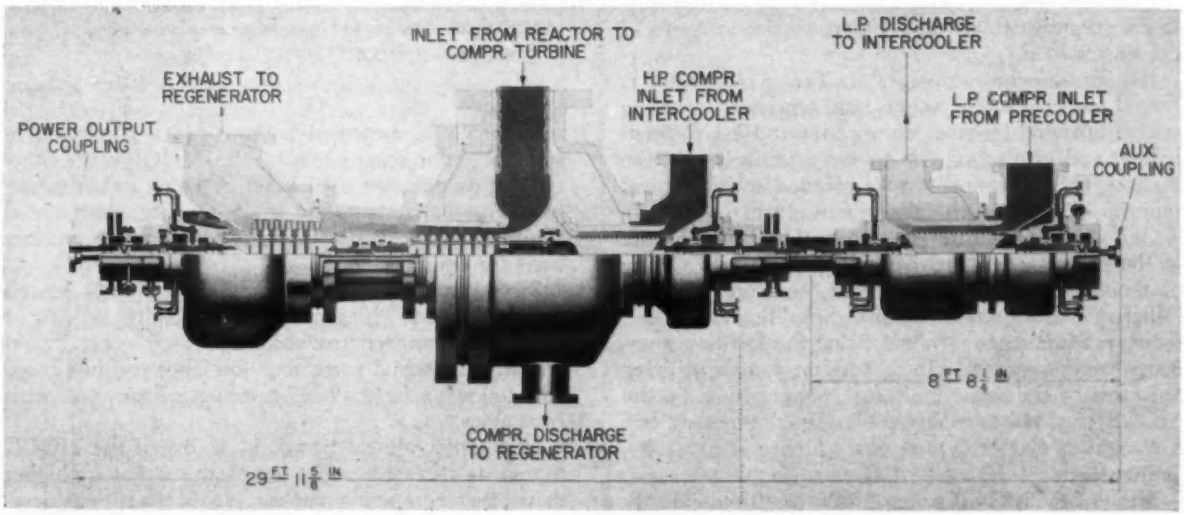
The entire turbomachinery package for the MGCR prototype will be approximately 32-ft long over-all and 8 ft in diameter across the flanges at the widest point. The machinery will weigh approximately 35,000 lb and is to be built by Westinghouse Electric Corp.

Astern operation of MGCR-powered ships probably will be obtained by a reversible-pitch propeller.

Special Characteristics of the MGCR

One principal operational advantage of the MGCR cycle is its ability to maintain an almost constant high efficiency over a wide range of power levels. Control of modern steam turbines is accomplished either by throttling steam to the first-stage nozzles or by controlling the number of inlet nozzles. In either case, a decrease in the efficiency of steam turbines occurs when operated at "off-design" points.

Fig. 3 MGCR machinery has independent power turbine at left, then moving to right, compressor turbine, high-pressure compressor, low-pressure compressor and power coupling for auxiliaries.


INLET FROM REACTOR TO COMPR. TURBINE
L.P. DISCHARGE TO INTERCOOLER
EXHAUST TO REGENERATOR
H.P. COMPR. INLET FROM INTERCOOLER
L.P. COMPR. INLET FROM PRECOOLER
POWER OUTPUT COUPLING
AUX. COUPLING
8 FT 8 1/4 IN
COMPR. DISCHARGE TO REGENERATOR
29 FT 11 5/8 IN

MGCR--marine propulsion plant

However, a gas turbine can be controlled by varying the density of gas flowing through the machine. In the closed-cycle gas turbine, flow rate is controlled by varying the inventory (and, therefore, pressure level) of the working gas without affecting volumetric flow. In this way, distribution of energy release throughout the machine remains practically constant and efficiency remains high. The inventory may be decreased by bleeding helium gas from the high-pressure compressor to an accumulator.

This wide range of high efficiencies is of particular importance when ships must operate under partial-power conditions for extended periods of time, as during a storm or in confined waters.

The closed-cycle gas turbine also has the advantage of extreme flexibility of operation. Output power can be varied from full power to zero, or vice versa, in a matter of seconds because of low transient thermal stresses in the power-plant components. These low stresses are obtained because the low heat-transfer coefficients of gas can be maintained adjacent to heavy sections and because low heat capacity is inherent in the lightweight machinery.

Typically, the MGCR turbomachinery can be safely started from cold condition much faster than existing steam plants, including those on nuclear-powered ships which require several hours for such start-up. Flexibility as related to maneuverability is important to any ship which runs in narrow waterways or has a requirement for rapid starting and stopping in port or at sea.

When compared to a pressurized-water system, the gas system has a major advantage in that it stores much less energy in the coolant and therefore permits a substan'ial reduction in containment requirements. Since the gas is chemically inert, possibility of chemical energy release will not add to containment requirements. Also, low thermal conductivity of the gas minimizes thermal shocks in the pressure-containing members and permits internal insula'ion of components containing the high-temperature coolant. These advantages can be employed to effect measurable improvement in the integrity of the reactor loop.

If a rupture or mechanical failure in the MGCR propulsion machinery occurs, an emergency cooling system operated by emergency power and using stored helium and/or atmospheric air can effectively cool the reactor. This operation can be effected within several minutes after any such failure or rupture.

Our analysis indicates, however, that heat capacity of the presently-designed MGCR core permits a delay of about an hour before emergency measures must be initiated to avoid possibility of fuel-cladding failure and fission-product release. In event that the first-line emergency cooling system fails, a back-up system utilizing an auxiliary fluid can limit fuel temperature. In the MGCR case, this auxiliary cooling medium is water.

Economics

Merit of the MGCR system to the maritime industry must finally be measured in terms of its economic performance. For comparison of the MGCR with other nuclear systems, we used latest available published reports on other systems and, as appropriate, exterpolated the information contained therein to provide uniform basis for comparison.

Since our studies show that capital costs for all nuclear-powered ships of the same rating are about equal, economic comparisons are based generally on operating costs and particularly on labor and fuel costs. The following factors have a strong influence on such economics.

High-temperature Operation—Ability of the MGCR to operate at reactor outlet temperatures that are higher than other competing nuclear plants permits achieve-

TABLE I

Comparative index of projected fuel cycle costs for 30,000-shp tankers with the following nuclear power plants (Plutonium credit of $12 per gram).

100% — Pressure Water Reactor
78% — Liquid Metal Reactor
66% — Organic Moderated Reactor
52% — Boiling Water Reactor
40% — Marine Gas Cooled Reactor

Lowest fuel consumption above is obtained by the use of a gas turbine, other reactors use steam turbines.

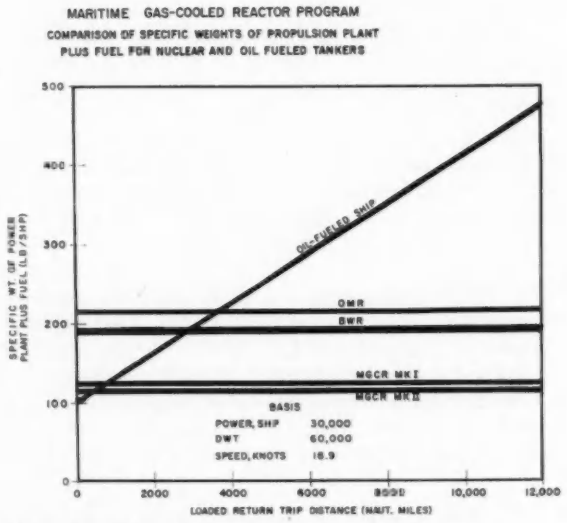


Fig. 4 Immediate advantage of nuclear propulsion plants is seen in their flat specific weight curves. MGCR plants show marked superiority over organic-moderated and boiling-water reactor plants.

of the future

ment of higher thermodynamic efficiencies (40% and above) at more reasonable capital cost than competing nuclear power plants or conventional power plants.

Simplicity of Operation and Maintenance—Simplicity inherent in the single-fluid system, together with the prospect of complete automation of control, will reduce requirements for operating personnel, and at the same time, of course, requirement for all the capital costs of providing for such personnel at sea. A history of extended, remote, continuous operation of gas turbines suggests that maintenance attention and cost on the MGCR will be held down by use of similar machinery.

Experience of operating many large aircraft power plants, and especially turbine-driven planes, with crews of only three or four people also permits us to hope that the crew requirements of simple but rugged, and automated maritime power plants can be reduced.

Compactness of Machinery—Compactness and low weight of the over-all power plant, achieved by use of a moderate-size reactor and compact propulsion machinery and by elimination of a bulky boiler, will permit an increase in the ship's available cargo space and weight capacity. A comparison of the machinery-plus-fuel weight per shaft horsepower for oil-fired systems, for MGCR and for other nuclear systems illustrates a marked superiority for the MGCR (Fig. 4). Compactness of the MGCR system, compared with the Pressurized Water Reactor, shows a saving of more than one-third in machinery space.

Low Fuel Cost—High efficiency of the MGCR and excellent neutron economy of the core result in lower fuel burnup, fabrication costs and inventory charges per shaft horsepower hour. Comparison of the MGCR fuel charges with those of certain competitive nuclear systems shows a marked advantage for MGCR against the best competitive systems, see Table 1.

The MGCR Program

Since the MGCR represents the wedding of two advanced subsystems—the gas-cooled reactor and the closed-cycle turbine—the prototype will be geared to operate at a maximum pressure of 800 psi and at a reactor outlet temperature in the range of 1300°F to 1500°F. The reactor will, at the lower temperature, achieve a basic cycle efficiency of 32%.

According to present schedules, test operations on the reactor are planned for early 1964. Two successive seagoing versions of the MGCR which have been studied are identified as Mark I and Mark II. These would operate at higher pressures and temperatures than the prototype and will achieve basic cycle efficiencies of 37% and 40%, respectively.

Conclusion

In summary, the foreseeable MGCR plants represent advances in power-plant technology and achievements in efficiency and economy which appear to exceed those promised for advanced oil-fired or other nuclear-powered systems.

GAS TURBINES FOR AIRLINERS

(*Continued from page 28*)

RA.29 that has the distinction of being developed specially for commercial aircraft. The Avon RA.29/1 that powered the 515-mph, 4-engine, 58-to-76 passenger, redesigned De Havilland Comet 4, is rated 10,500 lbt. This plane was placed in service across the North Atlantic by British Overseas Airlines in October, 1958. The turbojet has a 16-stage axial compressor and a 3-stage turbine. This engine is used in various medium-size airliners including the 480-mph Sud Aviation Caravelle I airliner. This plane with two engines at the rear has been supplied to Air France and Scandinavian Airlines. Advanced models of the Avon RA.29, with variable-area exhaust nozzles are being tested at 11,400 lbt and 12,500 lbt for take-off.

The latest British turbojet for airliners is the Rolls-Royce Conway. This is a 2-spool by-pass engine in which a portion of the air-flow from the low-pressure compressor is diverted around the engine and into the exhaust stream, providing additional thrust. It has a 7-stage low-pressure compressor, a 9-stage high-pressure compressor and a 3-stage turbine. The Conway, rated 17,500 lbt, will be used in 600 mph Boeing 708, 420 Stratoliners and Douglas DC-8 airliners for British Overseas Airways, Trans-Canada Airlines, Lufthansa, and Air Indiana International. The Conway 42, an advanced model, is being tested at 20,250 lbt for the 600-mph 4-engine Vickers VC.10 airliner, with engines at the rear.

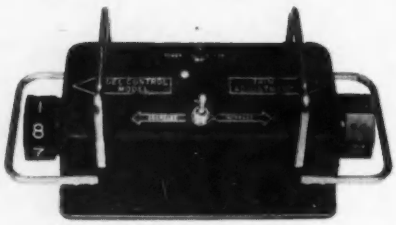
In the U.S.S.R., airliners powered with turbojets have been in regular service on Aeroflot routes for more than three years—ante-dating American accomplishments in this field. The engine that has made these flights possible is the Mikulim AM-3 which is an adaptation of a military engine used in Russian bombers. It has an 8-stage axial compressor and a 2-stage turbine and runs at about 6000 rpm. Despite its fewer rotating parts and lower rpm, it turns out the power—being rated 19,200 lbt at take-off. Two AM-3's powered the Tupelov TU-104, 50-passenger airliner when it was placed in service by Aeroflot in September, 1956. The improved AM-3M, with lower specific fuel consumption, is used in the newer 560-mph TU-104B airliner which has accommodation for 70 to 100 passengers.

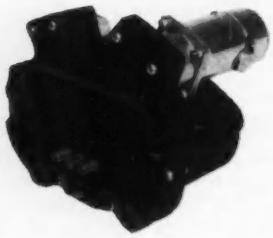
Commercial gas turbines have come far—future unlimited . . .

During the past eight years, commercial turbojets have increased in power from 5000 lbt to 20,000 lbt, and turboprops from 1540 ehp to 13,000 ehp. Airliners powered with these engines have increased in size from 40-passenger to 220-passenger aircraft and their range has increased tremendously. Speed of these airliners, however, has only increased from 500 mph to 600 mph, partly due to increased weight of the airliner offsetting the higher engine power available and partly due to the retarding effect of greater head resistance and drag.

Gains made in such a short period are truly impressive but are just a start. New concepts and requirements, changing economics and continual competitive pressures are bound to accelerate the rate of development. The surface of possibilities has just been scratched.

PRODUCT NEWS





LEAR DEVICE REDUCES HAZARDS, SPEEDS JET ENGINE TRIMMING

Lear, Inc. has announced development of a device to improve accuracy of jet engine trimming while reducing time and hazards usually associated with this critical operation.

Jet engine fuel controls must be adjusted periodically on the ground for maximum performance and operating economy. For example, idle, "military power" and water-injection flow must be adjusted. Normally, three men are required: one to read cockpit instruments; another to make adjustments; and a third to act as liaison between the other two. Line of sight is blocked and engine noise requires relay of information by hand signals. Men are exposed to potential hazards and in many communities, regulations limit ground operating time. Yet the water-injection adjustment requires that the engine has first been stabilized at military power. Under such limiting conditions, engine adjustments are not always accurate.

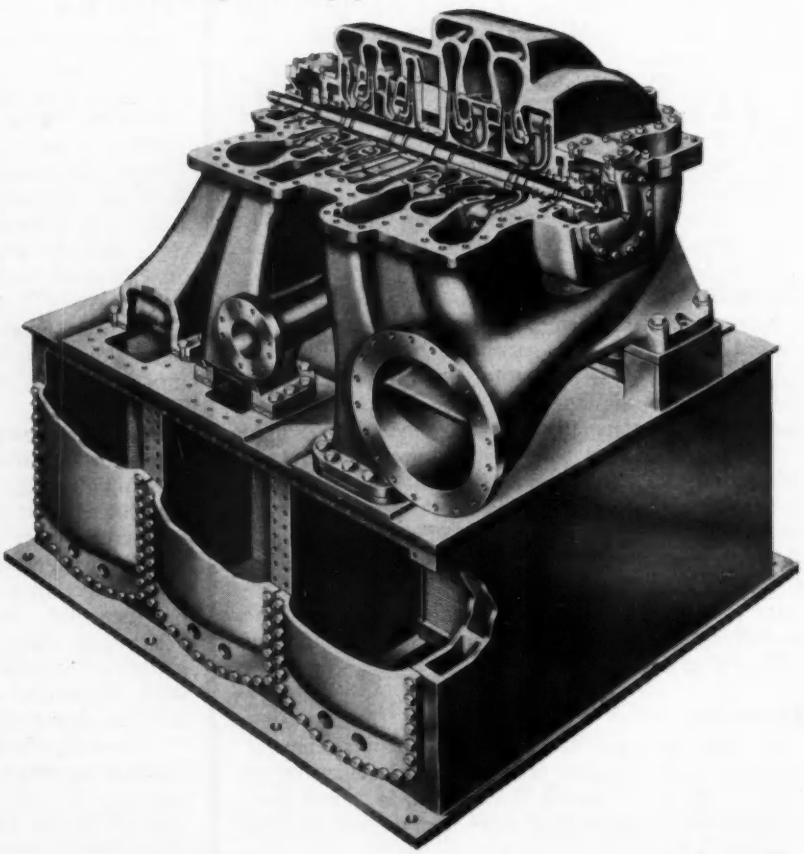
Lear developed for Pratt & Whitney a 3-element Remote Trimmer System that permits one man to perform the entire operation from the cockpit. The system uses a reversible, high-response servo actuator with three output shafts as shown. This servo is electrically connected to a control box, operated in the cockpit with instrumentation in full view. The system adapts to any fuel control. Control box has two knob-type switches, one to select the model of fuel control and a second to select the required adjustment. Once set, a "center-off" toggle switch is simply operated to left or right to decrease or increase trim.

The system weighs less than half that allowed by military specifications for such portable equipment.

CLARK'S CENTRIFUGAL COMPRESSOR FOR INDUSTRIAL USES

Clark Bros., one of the Dresser Industries, has a new high-efficiency, multi-stage, intercooled air compressor. It was designed to furnish "100-lb air" for oxygen plants, central air systems and other industrial air applications. Eleven are already on order or in service, five supplying high-purity air in steel mill oxygen plants and one in a West-Coast wind tunnel application.

Six sizes are available with horsepower requirements from 1000 to 8000 and capacities from 5000 to 38,000 cfm. Each is a complete package including matching driver, intercoolers and lubricating system. These Type H compressors are well-suited for single-unit 100% operation or as a high-capacity, base-load machine. Features include compactness through single-case construction; integral bearing supports cast with the case to assure permanency of alignment; back-to-back impeller design to give thrust balance; plus isolated bearing chambers and a unique seal porting system to keep lube oil from the air.



Compact Fuel Control by Hamilton Standard

Fuel controls for the Canadian Pratt & Whitney Aircraft PT-6 engine will be produced by Hamilton Standard Division, United Aircraft Corporation. The PT-6 is a free-turbine 450-hp engine for light propellor-turbine aircraft or helicopters.

The new JFC-50 control is the smallest ever designed by the Division. It has a 5-in. diameter and is 10-in. high and will meter 300 lbs of fuel per hour. The JFC-50 retains all essential functions of larger, more complex controls, including metering of fuel during starting, steady-state governing, acceleration and deceleration. It also protects against over-speed, over-temperature, or flameout regardless of load conditions on the free turbine.

Combination Combustion/Air-Turbine Starter by Bendix

New Bendix fuel-air combustion unit Type 36E73-2A doubles as air-turbine starter. It burns a mixture of compressed air and aircraft fuel and provides long-life starting capabilities for engines with high-energy starting requirements. Then, a simple movement of the selector switch allows air-turbine starting from the same unit by cross-bleeding compressed air from another engine to the turbine section of the starter.

A self-contained starting system, independent of outside support equipment, the new Type 36E73-2A also provides a two-start capability for each starter application—one start immediately following the other before a cooling period must be applied. The starter automatically locks in the start cycle and automatically disengages from the engine after starting.

Almasol Corp. Formed to Make Specialty Lubricants

This new firm has just been formed to produce a new line of lubricants and solid film coating materials said to have excellent heat, pressure and wear-resistant qualities. Almasol SFD Series 800 lubricants are claimed to operate at extreme high temperatures (up to 1900°F with a basic operating temperature around 1000°F) and with heavy loads. The Fort Worth company is owned by Lubrication Engineers.

New Flight Attitude Control System

Highly satisfactory tests of a new hot gas reaction valve for application to the flight attitude control requirements of space vehicles is reported by Sundstrand Turbo Division of Sundstrand Corporation, Pacoima, California.

Operating on hydrazine, the system has a response time of 10 milliseconds from electrical signal to full thrust. Two nozzles have been tested, one developing 33-lb thrust and the other 21½-lb thrust.

A system of three nozzles to control yaw, pitch and roll has been successfully tested for several hundred hours without any component failure and the combustion chamber can be blocked for extensive periods of time without flaming out.

The valve can be pulsed from a rate of 1 cycle per hr to a maximum of 30 cycles per sec. Continuous runs of 7000 cycles over a 5½-hr period have been conducted.

The Division is engaged in advanced research and development projects, both government contract and company-funded, in power generation, conversion and application.

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with these features:

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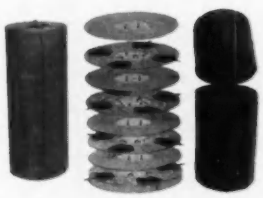
- Low pressure drop
- Choice of filter cartridges
- Large dirt storage area
- All steel welded construction
- In-out pressure gauges
- Quick action cover lifter
- 100 psi standard design pressure
  Higher pressures upon specification
- Swing bolt cover construction



HILCO FILTER CARTRIDGE TYPE FW-718 COMBINATION EXTENDED SURFACE AND DEPTH MICRO FILTRATION

HILCO FILTER CARTRIDGE TYPE PL-718 EXTENDED SURFACE FOR EXTREMELY HIGH FLOW RATES

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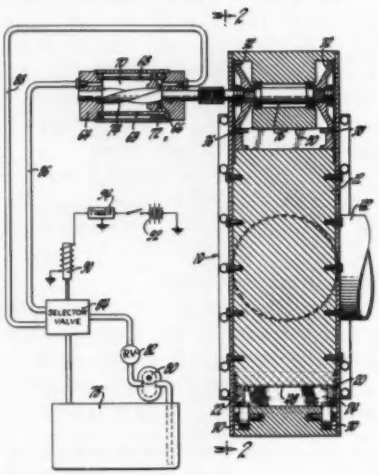
THE HILLIARD CORPORATION
210 WEST FOURTH STREET
ELMIRA, NEW YORK

GT PATENTS

REGENERATORS AND SEAL THEREFOR (2,893,699) 7 claims Inventor William C. Dubniak, assignor to General Motors Corporation, Michigan. The invention relates to regenerative heat exchangers and more particularly to a sealing arrangement for regenerators that employ movable matrices. These regenerators, in general, comprise a housing having separate hot and cold fluid passages and a movable matrix in the passages to soak up heat from the hot fluid to transfer it to the cold fluid. Regenerators are commonly used with gas turbine power plants to absorb waste heat from the turbine exhaust gases and to transfer this heat to the air passage of the power plant at some point upstream of the combustor. The invention provides a close running-fit partition seal during the short-duration movement time of the matrix and provides a positive-pressure partition seal during the long-duration stationary heat transfer period. A transverse section of a drum-type regenerator incorporating the positive matrix seal is illustrated, Fig. 1 of patent.

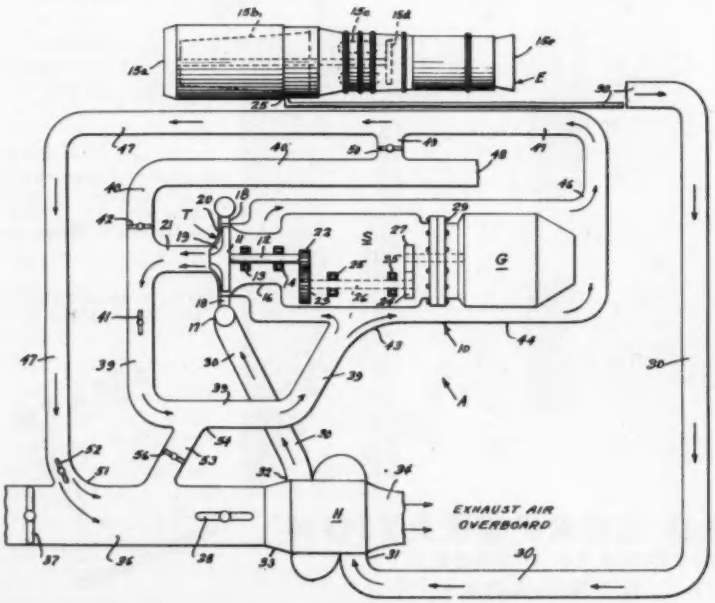


FUEL METERING SYSTEM FOR STARTING GAS TURBINE ENGINES (2,892,309) 8 claims Anatole J. Sipin, New York, N. Y., assignor to Sperry Rand Corp., Delaware.

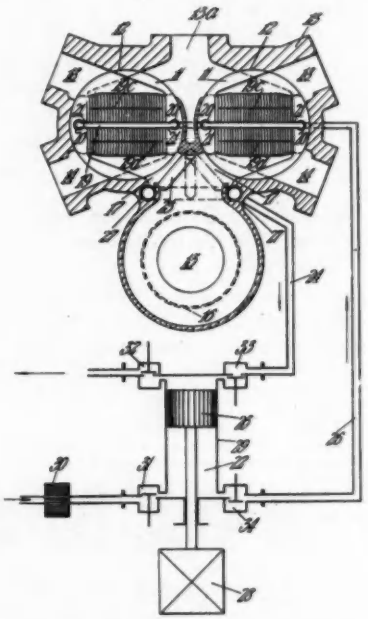
HEAT EXCHANGERS OF THE ROTARY REGENERATOR TYPE (2,892,615) 6 claims Walter S. Misener, Syracuse, N. Y., assignor to Carrier Corporation, Syracuse, N. Y.

ROTARY REGENERATIVE AIR PREHEATER (2,892,616) 2 claims Werner Firgau, Heidelberg-Pfaffenfrund, Germany, assignor to Svenska Rotor Maskiner Aktiebolag, Naka, Sweden.

SELF-COOLED TURBINE DRIVE (2,893,204) 6 claims Inventors Robert J. Anderson and Joseph T. Hamrick, assignors to Thompson Ramo Wooldridge Inc., Ohio. The invention concerns a self-cooled air turbine-driven generator or "power pack" for use in high-speed aircraft where environmental operating temperatures in the range of 640° to 880°F may be expected. A self-cooled air turbine-driven generator utilizing regenerative turbine exhaust intercooling, according to the principles of this invention, is shown, Fig. 1 of the patent.



HEAT EXCHANGERS (2,893,697) 9 claims Inventor Waldemar Hryniszak, assignor to C. A. Parsons & Company Limited, England. This invention relates to heat exchangers, more specifically to recuperative heat exchangers, wherein the flow paths are of small hydraulic diameter and particular care has to be taken to prevent clogging. Objective of the invention is to provide a cleaning means for such heat exchangers. Arrangement of a heat exchanger and one form of cleaning device is shown, Fig. 5 of patent. The cleaning comprises filtering a gas to remove part of dust, and passing filtered gas through a heat exchanger matrix, and intermittently introducing air into the matrix intermediate to its inlet and outlet ends and blowing the air through the matrix toward both inlet and exhaust passages to remove any unfiltered dust and other particles Part of the dust-laden air is drawn off by suction.



IGNITOR CONTROL (2,899,798) 1 claim Claude O. Broders, Simsbury, William W. Jacobus, Columbia, and Arthur B. Swenson, Glastonbury, Conn., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Navy.

COMBUSTION CONTROL ARRANGEMENT FOR AFTERBURNERS (2,899,799) 1 claim Earl O. Setterblade, Stratford, Conn., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy.

(Continued on page 41)

GT PRODUCT TECHNICAL FILE

Data on Kelsey-Hayes Superalloys

Technical bulletins covering performance data of vacuum induction-melted WASPALOY and M-252 superalloys are now ready for you from Metals Division of Kelsey-Hayes. Each is an 8-pager and includes the following: alloy and chemical description; physical constants; tables and charts on mechanical properties; isostress curves; plus heat treating and finishing data.

Both alloys have high-temperature, high-stress properties and are in current use in jet engines, missiles, process- and nuclear-industry applications. Copies of the bulletins or more information can be obtained via the Reader Service card.

Description of Gas Turbine as Standby Steam/Electric Generator

Here's a 10-pager from Boeing's Industrial Products Division. It tells the story of a complete gas turbine-powered package for providing electrical power or steam. Typical application would be as a marine on-board auxiliary power source to supply economically all in-port requirements for steam and electric power.

As a generator it produces 100 kw and as a steam source provides up to 1700 lb per hr of steam at 150 psig. Features, performance, installational data, system diagrams and specifications are given.

This booklet tells the whole story of this versatile and compact unit. Need steam and/or electrical power? If so, you'll want to send for this booklet for your files.

Vector Gas Turbines Described

A well-done 4-page brochure from Vector Corporation illustrates their gas turbine, shows a well-labeled section and gives its specifications. Applications listed include use of shaft-power versions, use as a portable, self-contained direct- or indirect-fired air heater and as an aircraft primary or auxiliary power unit.

Externally clean, light-weight and having small frontal area and moderate diameter, this gas turbine should prove suitable for many applications. You'll want to know more about it so send for this brochure.

Flexible Coupling Catalog Is Valuable Reference

If you can use a good guide to flexible coupling selection and application, Thomas Flexible Coupling Company's Catalog No. 60 is for you. It's an up-to-date combination of their Catalogs 51 and 51A with added information.

Thomas Flexible's entire line—miniature couplings, standard series, extra high-speed series and special units—are listed and described. Much of the catalog is devoted to installational data with diagrams, tables and load capacities, all referred to each type and size.

Other data includes information on bore and keyway standards, dynamic balancing and a discussion of misalignment. To get your copy, use the Reader Service card.

Tube-Forming Brochure From Aeroquip

"Tight-Bend" tubes, always a problem in getting compact designs with smooth gas flow, is the subject of an aircraft engineering bulletin from Aeroquip Corporation. This 8-pager tells how such bends are formed through a cold process to short-radius bends of 1:1 or less with wall-thickness control and minimum thinout at the outside radius.

Aluminum, steel stainless and other alloys are fabricated in sizes ranging from ½- to 3-in. tube OD both as complete assemblies or as tight-bend components. Space-saving advantages are obtained without sacrifice in strength, flow or pressure drop characteristics.

Here's one answer to getting a fit in tight envelopes. Ask for Aircraft Engineering Bulletin No. 25.

Garrett Brochure Tells Reliability Story

AiResearch Manufacturing Division of Garrett Corp. tells how reliability of their gas turbine compressors, shaft power units and combination units has improved through the years. Clear, understandable graphs tell of the reduction in operational delays; increase in operating time and accumulated starts without difficulty; and of the resulting increased hourly period between overhauls.

Product descriptions and applications, plus a listing of engineering and sales offices, complete this attractive brochure. You'll want one; ask for File Code SP-S-9.

Two Brochures from GE

A 6-page foldout from General Electric is a Progress Report on their T58 gas turbine. It tells the story of the rugged and diversified tests that have proven the reliability and versatility of these units.

Exploded views show the components and tell of their features. Guarantee and actual fuel rate curves are also shown, along with a chart showing total experience hours. Brief specifications are also given.

The second brochure, a 4-pager, tells the story of their T64, billed as ". . . a workhorse powerplant to satisfy military requirements for high-performance support aircraft." Performance figures are given for both turboprop and turboshaft versions. Versatility, reliability and ease of maintenance are stressed along with details of the continuing development program.

For your copies, use the Reader Service card.

"Bi-Metallic Castings by Tickle Engineering"

This guide to the casting method of molecularly bonding aluminum to ferrous metals, nickel, titanium, etc. by the Al-Fin patented process is available from the Arthur Tickle Engineering Works. The brochure illustrates applications and a representative selection of Al-Fin constructions in varied industrial fields.

Al-Fin construction might offer the answer to a design problem involving heat transfer, joining bearing surfaces, abrasion and wear resistance, weight saving, cost reduction, or oxidation resistance.

TECHNICAL BRIEFS

The JT12 Pratt & Whitney Aircraft's 3000-lb. Thrust Turbojet Engine by Davis G. Phinney, Assistant Chief Engineer, Pratt & Whitney Aircraft. (No. 103U, SAE National Aeronautic Meeting, Los Angeles, California October 5-9, 1959)

"In the considerable array of high-performance aircraft engines of various kinds which have been developed over the years, Pratt & Whitney Aircraft's JT12 3000-lb thrust turbojet, also known to the military as the J60, stands quite unique. Significantly, the engine was at its inception, and still is, a totally company venture in that no government funds have been allocated to the support of this engine.

"The field the JT12 was to enter was already highly competitive and as it turned out it was to be one and one-half years from the start of design to the first firm order. Table I lists current firm applications:

TABLE I.

North American	T-39
McDonnell	Model 119
Lockheed	Jet Star
Republic	Swallow
Fairchild	SD-5
Canadian	CL-41

INITIAL MANNED DELIVERY COMMITMENTS

Production (3000 lb)	Oct. 1960
Advanced (3300 lb)	Dec. 1961

"Because of the limitations of private support, the intent of the JT12 design was to take full advantage of known technology but to avoid any major excursions into wholly new areas. General design of the JT12 is similar to the JT3. Many specific features of the JT4 have been used and a few of the J52. Knowing the service-ability aspects of other turbines, these features were carefully investigated during design of the JT12.

"How did the program go? Like this: (1) the successful demonstration of altitude fuel consumption in 1958: (2) successful flight testing April, 1958; (3) on-time delivery of initial prototype engines with subsequent reports received of customer satisfaction as to their operation; (4) successful completion of the official 50-hr Pre-Flight Rating Test; and (5) the completed unofficial 150-hour qualification test only 16 months after the first engine run."

Future Applications of Ducted Fan Powerplants by Neil Burgess, Manager, and A. P. Fioretti, Manager, Applications Engineering, Commercial Engine Operation, Flight Propulsion Division, General Electric Company. (No. 103V, SAE National Aeronautic Meeting, Los Angeles, California, October 5-9, 1959)

Three basic arrangements presently being used for ducted fan engines are:

Type "A" is a gas generator using a power turbine to drive a ducted fan through a mechanical gear train. This configuration uses a conventional fan or propeller but has the disadvantages associated with a large mechanical gear train.

Type "B" is an axial-flow compressor which employs the initial stages to perform the dual function of ducted fan and initial stages of the gas generator compressor. At some intermediate position in the compressor, the by-pass air is ducted around the remainder of the gas generator. This mechanical arrangement, which is integral with gas generator, can be used with either a single or twin-spool gas generator.

Type "C" referred to as an "aft fan" engine, is a basic gas generator of either the single or dual-spool type with an independent turbine and ducted fan driven by the exhaust of the gas generator. This arrangement incorporates an aerodynamic coupling between the gas generator and ducted fan thereby allowing for a more flexible installation than the mechanical or integral units previously discussed.

A distinct application of the ducted fan engine is now in early stages of development for vertical take-off aircraft. There are many possible combinations, a few being described in the paper. For example, by mounting turbine blades at the radial tip of the large fan blades in the wing, it is possible to develop a very lightweight fan driven by gas generator exhaust which is diverted to these tip turbine blades during the take-off and landing phase.

The paper concludes that the ducted fan powerplant offers an excellent means of tailoring a basic gas generator to a multitude of different aircraft missions with ability to optimize both propulsive efficiency of the system and the thermodynamic cycle involved.

The Combined Steam Turbine-Gas Turbine Plant For Marine Use by Robert G. Mills, Commander, USN; Head, Internal Combustion and Gas Turbine Engine Branch, Bureau of Ships, Navy Department, Washington, D. C. (No. 59-A-237, Gas Turbine Power Div., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

As the gas turbine is becoming more widely accepted as a reliable prime mover, numerous investigations are being made to determine advantages of the combined steam turbine-gas turbine (short title: COSAG) type of power plant for marine use.

Main advantages lie in its potential for superior plant efficiency for certain arrangements and in its promise of marked savings in space and weight for other combinations. In all instances, reference is made only to the main propulsion plant, including necessary main engine auxiliaries.

The combined cycle offers important advantages for marine use in three respects:

1. For destroyer, frigate, and escort types, the parallel COSAG plant (steam plant for base load or cruising, parallel gas turbine plant for high-power operation) is a simple means of attaining significant savings in machinery size and weight and modest savings in fuel rate at all cruising speeds.

2. The COSAG plant with an unfired steam generator (gas turbine exhaust is the heating media) shows excellent efficiencies, comparable to those of very large marine steam plants, in units having 20 to 40% of the larger steam plant power. This promises extension of high efficiency into the middle and lower power ranges, making the turbine plant competitive efficiency-wise with the large marine diesel in the freighter, tanker and comparable ship types.

3. The COSAG plant with a pressure-fired steam generator will allow considerable weight and space savings, as compared to the normal steam plant, for very high-powered ships.

Gas-Turbine Reliability Control Procedures by Robert R. Brown, Head, Nuclear and Advanced Engine Controls Section, Bureau of Aeronautics, Department of the Navy, Washington, D. C. (No. 59-A-219, Aviation and Gas Turbine Power Divns., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

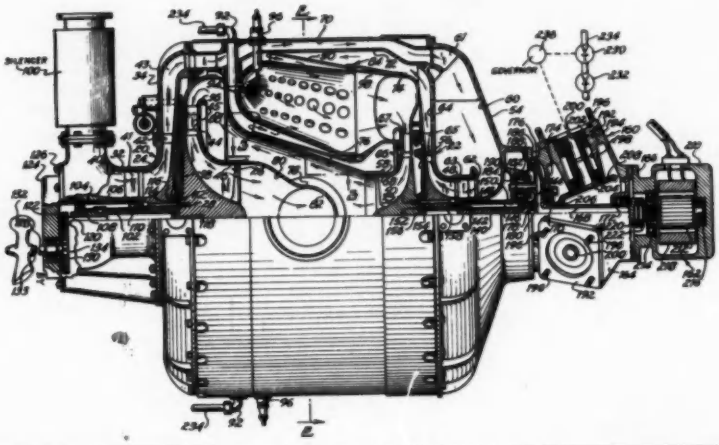
Reliability of repeatedly-used systems, such as engines of manned aircraft, requires consideration of seriousness and probability of malfunction occurrence as well as the number. This paper describes development of a procedure for analyzing those malfunctions in order of seriousness of result. Examples of design practices which reduce seriousness of a possible malfunction are given. Areas in which further work is needed are described.

(Concluded on page 42)

PATENTS . . . .

(Continued from page 36)

VARIABLE-SPEED GAS TURBINE (2,895,295) 20 claims Paul G. Carlson, assignor to Solar Aircraft Company, San Diego, Calif. This invention relates to gas turbine power plants and has particular reference to a compact variable-speed gas turbine especially adapted for use as a marine propulsion unit or as an auxiliary gas turbine compressor unit in aircraft. The power plant is small and light for the power developed and is suitable for small boats. A compact power plant comprising a casing, first and second coaxially-aligned, mechanically-independent compressors; first and second mechanically-independent turbines within the casing and immediately adjacent to their respective compressors and coaxially aligned therewith; means of mechanically coupling first and second stage compressors respectively to form independent low and high-pressure turbine units. A partially sectioned side elevation is shown in Fig. 1.



"HOT STREAK" IGNITION ARRANGEMENT FOR AFTERBURNER FUEL CONTROL SYSTEM (2,892,307) 6 claims Paul C. Mangan, Pittsburgh, Pa., and Wayne E. Kohman, Kansas City, Mo., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa.

British Patents

IMPROVEMENTS IN OR RELATING TO AXIAL-FLOW COMBUSTION CHAMBERS (798,474) 19 claims Bristol-Aero Engines, Ltd., Stonebridge House, Colston Ave., Bristol 1, England.

BLADED ROTOR CONSTRUCTIONS FOR FLUID FLOW MACHINE (798,689) 13 claims Rolls-Royce, Ltd., Nightingale Road, Derby, England.

ROTARY REGENERATIVE HEAT EXCHANGERS (798,698) 8 claims Svenska Rotor Maskiner Aktiebolaget, Nacka, Sweden.

COMBUSTION EQUIPMENT FOR GAS TURBINE ENGINES (799,605) 11 claims Rolls-Royce, Ltd., Nightingale Road, Derby, England.

FOR THOSE GAS TURBINE INSTALLATIONS WHERE IT IS NOT PRACTICAL TO APPLY EPSOM SALTS TO INHIBIT THE VANADIUM AND SODIUM CORROSIVES IN RESIDUAL FUEL OILS, WE RECOMMEND THAT YOU APPLY BARSAD ADDITIVE.

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Pat. Pending

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(Continued from page 40)

Overhaul Shop Planning For The P&WA Turbojets by Ernest C. Norton, Facility Planning Group, Service Department, Pratt & Whitney Aircraft, East Hartford, Conn. (No. 59-A-299, Aviation and Gas Turbine Power Divns., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

Advent of the jet-powered airplane brought with it a sweeping change in the whole concept of engine maintenance and overhaul. Relatively sudden introduction of the turbojet engine with its unique overhaul shop requirements meant in many cases, construction of completely new facilities. This gave opportunities for methods and planning engineers to apply the latest techniques in overhaul processes and shop layouts. The aircraft engine, however, does not lend itself to automation in general owing to the relatively low overhaul production rates, continual modifications in designs, changes in overhaul requirements and absolute need for rigid quality control.

Nature of the turbo-jet engine, its overhaul requirements and the type of overhaul facility that results are described in the paper which is well worth reading.

Development Of A Maintenance Program For Jet Transport Aircraft by John F. Roche, Manager of Aircraft and Systems Engineering, Trans-World Airlines, Inc., Mid-Continent International Airport, Kansas City, Mo. (No. 59-A-187 Aviation and Gas Turbine Power Divns., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

Introduction of jet-transport aircraft this past year to the aviation transport industry has posed many problems of technical training, operating techniques, ground support equipment and maintenance planning.

Not the least of these has been the problem of analyzing the design concept and mechanical details of this new and different machine to resolve a complete detailed inspection and maintenance program for safe, economical and reliable operation of the aircraft.

This paper, noting several design features of the new jet-type transport aircraft which distinguish them from their piston-engined predecessors, reviews a number of considerations which must be resolved in developing a practical maintenance program. An approach to a balanced solution is outlined. The paper further presents several typical maintenance deficiencies found in transport aircraft to emphasize the need to "design" for maintenance.

Turbine Propeller Power Plant Airline Maintenance by Donald W. Crosby, Maintenance Engineering Department, Eastern Air Lines, Inc., Miami International Airport, Miami, Fla. (No. 59-A-189, Aviation and Gas Turbine Power Divns., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

This presentation includes a brief description of the Lockheed 188A gas-turbine propeller power plant installation which highlights the major maintenance features. Maintenance procedures are outlined and the early maintenance experience is reviewed. A short but excellent maintenance paper.

Jet-Engine Trend Analysis by Paul J. Bruneau, Head, Power Plant Maintenance Section, Bureau of Aeronautics, Department of the Navy, Washington, D. C. (No. 59-A-297 Aviation and Gas Turbine Power Divns., ASME, Annual Meeting, ASME, Atlantic City, N. J., week of November 30, 1959)

This paper makes the point that until perfect component reliability is reached and jet engines can be engineered and built so that all parts and components wear out simultaneously at a predictable time, any trouble-shooting tool that will aid in detecting signs of incipient failure, before the fact, is life insurance and money in the bank.

The particular trouble-shooting tool discussed is the recording of certain significant indices—oil consumption and pressure, run-down time and exhaust gas temperatures—of engine performance to establish a profile of normalcy for each individual engine. A consistent trend away from this norm is the red light for trouble and until the cause for the departure is isolated, the engine is to be considered unsafe for use.

Mr. Bruneau then outlines some recorded items with possible causes and some results encountered. He ends by saying that moderate success has been obtained by the Jet Trend Analysis Program to date.

AIRCRAFT ENGINES of the WORLD, 1959/60
by Paul H. Wilkinson

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AVCO Corporation, Lycoming Division 4

Bendix-Aviation Corp., Scintilla Division ..... 3rd Cover.
Boeing Airplane Company ..... 1 & 8

Gas Turbine Power Division, ASME 2
Garrett Corporation, AiResearch Mfg. Company 3

Hilliard Corporation 35

Norris & Associates, R. S. 40
Nugent & Company, Inc., Wm. W. 8

Synchro-Start Products, Inc. 40

Westinghouse Electric Corporation 6
Wilkinson, Paul H. 42
Woodward Governor Company ..... 2nd Cover

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